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THE BROWNS FERRY NUCLEAR PLANT FIRE

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PREFACE

I was a consultant to the Nuclear Regulatory Commission Staff during its evaluation of the Browns Ferry fire. The Staff issued its Safety Evaluation Report containing its finding with regard to their evaluation on February 23, 1976, and Supplements on June 18, 1976, and July 3, 1976. The views expressed in this paper represent my own personal opinions and do not necessarily reflect the views of the NRC Staff; however, they are consistent with those expressed by me to the Staff and the Advisory Committee on Reactor Safeguards.

ABSTRACT

A fire in the Browns Ferry Nuclear Plant involved polyurethane foams used to plug leaks at the point of cable penetration from the Reactor Building. The fire also involved the polyvinyl chloride cable insulation but no nuclear material. A candle used for leak detection ignited the polyurethane to start the fire which spread rapidly to the cables. Lack of qualified, experienced, fire protection staffing contributed to the conditions which resulted in a direct loss of $10 million and an indirect loss of $30 million related to business interruption. Contributing to the rapid propagation and high loss were factors such as: poor design; fire detection and fire suppression systems were provided only on a partial or limited basis; polyurethane foam was used as a pressure differential seal/firestop; cable trays and seal/firestop installations did not meet design criteria. The most important element in improving the risk would be the obtaining of management interest in fire safety.

INTRODUCTION

On March 22, 1975, a fire occurred at the Browns Ferry Nuclear Plant (BFNP) located near Athens, Alabama which is the only nuclear plant operated by the Tennessee Valley Authority at this time. The construction permit for this General Electric designed plant was issued in 1966. Operating licenses were issued for Units 1 and 2 in June 1973, and June 1974, respectively, with each unit capable of producing 1100 MW (electrical). Units 1 and 2 were on line at the time of the fire, producing about 2200 MW (electrical). Unit 3 was under construction at the time. An aerial view of the complex is shown in Figure 5 (a schematic in Figure 4).

The direct loss from the fire was estimated to be approximately $10 million in addition to indirect losses related to business interruption. With the loss of this electrical generation capacity for approximately 18 months, the Tennessee Valley Authority had to purchase electrical energy from other plants. The fossil fuels for these plants was estimated at costing the Tennessee Valley Authority between 1/3 and 1/2 million dollars per day for a total of $200 million or more.

EVENTS PRECEDING THE FIRE

The Browns Ferry Nuclear Plant was designed so that the airflow moves from the outer areas including the Control Bay to the Reactor Building (secondary containment). In the construction of Unit 3 there was a requirement to remove a temporary barrier wall separating Unit 2 and Unit 3. However, because of many leaks between the air zones, the air handling system was recognized as not being capable of maintaining the required pressure differential during the breach of the barrier between Unit 2 and 3. To correct this situation and allow for the breach, a plan was developed to identify all of the leaks and to seal them.

One leak was identified in a pressure differential seal at a point where cables penetrated the wall between the Cable Spreading Room and the Reactor Building. This particular pressure differential seal was also designed to perform the function of a firestop, i.e., to prevent the spread of a cable fire from one side of the wall to the other.

LOCATION OF IGNITION

The cable penetration of concern is an array of 10 trays, two stacks of five. These 10 trays pass through a 1.22m x 1.22m (4'x4') opening in the 66cm (2') thick reinforced concrete wall between the Cable Spreading Room and the Reactor Building. Design for the pressure differential seal and firestop consisted of a steel plate having 10 sleeves measuring 13cm x 46cm (5"x18"), one for each tray. The cable tray stops at the wall, the cables span a short distance, about 25cm (10") pass through the sleeve, span another 25cm distance, then back into the tray on the other side. The sleeve was then filled with foamed-in-place polyurethane. A fire retardant or protective material was then applied on each of the exposed polyurethane faces. As installed, however, the seal/firestop was placed at the Reactor Building side of the wall rather than the center of the wall. Also, at the time of concern, the protective coating was not in place as designed.

IGNITION

On March 22, 1975, at approximately 12:15 P.M., Tennessee Valley Authority workers in the Cable Spreading Room were in the process of plugging this leak in the wall between the Cable Spreading Room and the Reactor Building. The precise location of the leak was identified by the use of a candle, i.e., noting the movement of the candle flame caused by airflow.

At 12:20 P.M., a worker placed a candle in close proximity to the seal/firestop to identify the precise location of the leak. He then stuffed polyurethane foam sheet material into this area in an effort to plug the leak. The candle was then again placed in close proximity to determine if the leak had been sealed.

The candle flame was drawn toward the seal/firestop because of the airflow and the sheet-foam material ignited.

THE FIRE

Attempts were made to extinguish the fire by beating out the flames with a flashlight and by smothering with rags. One of the workers then left the Cable Spreading Room and returned with a CO_2 extinguisher, but the fire continued, and after several minutes it was apparent that the fire was moving through the seal/firestop. Workers left the Cable Spreading area for the Reactor Building where they discharged extinguishers on the opposite side of the wall and shortly after, the manual CO_2 system in this room discharged.

At 12:34 P.M., 19 minutes after ignition, the Shift Engineer was notified of a fire in the "Reactor Building, location unknown" and the fire alarm was sounded.

Firefighting efforts continued in the Reactor Building with fire extinguishers. Smoke began building up; personnel were unable to breathe and breathing apparatus was beginning to be used. However, the dense smoke and trouble with the breathing apparatus (discussed later) were major deterrents to the fire fighting efforts.

Meanwhile in the Control Room, the Operator was having trouble with erratic operations of Unit 1 pumps and with indicating lights on the panels. This occurred at approximately 12:40 - 12:43 P.M., 20 to 23 minutes after ignition. At 12:45 the lights went out in the fire area and all bystanders were ordered out of the fire area. At 1:09 P.M., the Assistant Shift Engineer called the Athens Fire Department, 49 minutes after ignition. The Athens Fire Department arrived at the plant at approximately 1:30 P.M., and were at the scene of the fire by 1:45 P.M., 85 minutes after ignition. Shortly after arrival, the Athens Fire Chief made the recommendation to use water on the fire, but permission was not given by the Plant Superintendent.

With little or no visibility, fire fighting was practically abandoned. However, with the use of breathing apparatus, life lines, and temporary lighting, the Tennessee Valley Authority personnel, with the assistance of the Athens Fire Department continued to monitor the spread of the fire and to apply dry chemical extinguishers occasionally.

At 3:10 P.M., the Tennessee Valley Authority Central Emergency Control Center in Chattanooga, Tennessee, was manned and the Nuclear Regulatory Commission notified.

The CO_2 system in the Cable Spreading Room was discharged three different times and the fire in this area was reported extinguished at 4:20 P.M.

At 5:30 P.M., (4 hours, 10 minutes after ignition) the Plant Superintendent received permission from Tennessee Valley Authority management through the Central Emergency Control Center (Chattanooga, Tennessee) to use water on the fire, but to use extreme caution. However, its use was considered too risky and it was not used.

At 6:00 P.M., the Athens Fire Chief again recommended use of water. At 7:00 P.M., the Plant Superintendent agreed to the use of water (6 hours, 40 minutes after ignition). The initial effort to use water was unsuccessful because the interior hose line and nozzle was not capable of a stream which could reach the burning trays. The Athens Fire Chief then obtained a nozzle from one of his trucks. However, the threads would not match and it would not stay on the hose. The original nozzle was placed back on the hose and the Shift Engineer climbed up scaffolding, jammed the nozzle in the tray such that it was directed at the fire. At 7:15 P.M., no evidence of continued burning was found. The area was sprayed again, and the fire declared out at 7:45 P.M. (seven hours and 25 minutes after ignition). The extent of fire spread is shown in Figure 12.

CONTROL ROOM OPERATIONS

At 12:34 P.M. the Shift Engineer was notified of a fire in the Reactor Building at an unknown location. Operators began watching the control console looking for abnormalities. At approximately 12:40 the first alarm, related to the need for Emergency Core Cooling Systems, caused by the fire in the control, signal and power wiring was received. This alarm was noted as being contrary to the observed status of the Unit. Other alarms continued to come in, panel lights began getting abnormally bright and then dim or going out. At 12:51 Unit 1 was scrammed,* 31 minutes after ignition and 17 minutes after notification of fire to the Control Room. At 1:00 P.M. (nine minutes later) Unit 2 was scrammed because abnormal indications had begun to be received on it also.

As the fire continued to burn in the control, signal and power cables, some of the Emergency Core Cooling Systems began to operate in their design modes. However, at that time these systems were not required and they were secured by the operators. Shortly after, the main steam isolation valves closed and all steam-driven feed water pumps were lost and the reactor was isolated from its normal heat rejection system, the condenser.

At this point, because of the fire, remote control of other Emergency Core Cooling Systems was lost. In short, all Emergency Core Cooling Systems were lost, and with decay heat in the reactor core, the water temperature rose and core pressure began to rise to the relief valve set points.

Unit 2 was less affected by the fire and its long-term cooling was satisfied through the use of normal shut-down systems as designed. Unit 1 was further depressurized and long-term cooling established through the use of a condensate booster pump. One additional problem arose on the cooling of Unit 1 at about 6:00 P.M. when the remote control capability for pressure relief of Unit 1 was lost. When this occurred, the pressure in Unit 1 core rose above the rated head of the condensate booster pump. Drain valves were not operable from the control room and, because of dense smoke, were inaccessible for manual operation. It was then determined that a solenoid valve supplying control air to the relief valves had failed close due to fire damage to the electrical cables. This solenoid was then bypassed by manual repair actions and control of the relief valves restored. Adequate core cooling was then reestablished.

EXTENT OF FIRE

The fire originated at the seal/firestop on the Cable Spreading Room side, passed through the seal and then burned along cables to cover an area roughly 9m x 12m (30' x 40'). A total of approximately 2,000 individual control, signal or power cables were burned. It is estimated that about 1815 kg (4,000 pounds) of polyvinyl chloride insulated cable burned releasing an estimated 635 kg (1,400 pounds) of chloride to the Reactor Building.

*The control rods were inserted stopping the fission reaction.

EXISTING FIRE PROTECTION SYSTEMS (AS OF MARCH 22, 1975)

At Browns Ferry there were interior hose lines, some preconnected, some unconnected, throughout, with the exception of the Control Building. A low pressure bulk CO_2 storage tank provided automatic protection for the diesel generators and associated electrical board rooms, lube oil purification room, permanent records storage room, fuel oil dispensing room, and the paint shop. Manual CO_2 coverage and detection was provided for the auxiliary instrument rooms, computer rooms and the Cable Spreading Room. Automatic water spray protection was provided for the turbine head ends, turbine oil tanks, the high pressure coolant injection pumps, outdoor transformers, and the hydrogen trailer port. Automatic sprinklers protected the carpenter shop and the high pressure oxygen and acetylene bottle storage area. First aid CO_2 and dry chemical extinguishers were provided throughout. In addition, the plant fire brigade was available as well as off-site mutual aid assistance.

In spite of this protection there were major areas of the facility without automatic detection or protection. The Reactor Building was virtually unprotected. There were no interior hose lines in the Control Building.

FACTORS RELATED TO CAUSE OF DISASTER

In the design of a nuclear power plant, the control, signal and power cables associated with safety related systems are identified as Class IE circuits. As such, these circuits are provided in duplicate, i.e., one set identified as Division I and one set as Division II. The requirements for separation of these Divisions is not clear. In those documents which do address this question, the words which are related to Division I and II separation may be interpreted differently by different people. Some think in terms of barriers, others in terms of distance separation, and a fire protection engineer in terms of rated wall construction providing a specific degree of fire resistance as judged by a standard temperature/time exposure condition.

In the case of Browns Ferry, this separation was largely provided by spatial separation. Spatial separation can be utilized provided that other features such as detection and suppression (protection) are provided. The Browns Ferry fire spread through an area where there was inadequate separation of Division I and Division II cables and where there was no automatic fire protection, i.e., Reactor Building.

In addition to deficiencies of design there were other operational problems and factors which were manifested during the fire. A brief outline of these follows:

Fire detection or fire suppression systems were provided on a partial or limited basis - the primary line of defense was manual fire fighting for some of the areas such as the Reactor Building.

The pressure differential seal/firestop was designed utilizing urethane foam. This design was also tested under fire conditions and considered to have passed the test (the fire conditions did not consider pressure differential leaks, lack of protective covering, or exposure fire conditions).

The cable trays and seal/firestop installation did not meet design criteria; some of the trays were overloaded, not installed in accord with design, nor maintained in accord with design.

There was no written or approved procedure for leak testing; an open flame candle was used.

No hot work permit system was utilized.

Previous fires caused by same operations two days prior did not receive adequate concern.

The ventilation system in the Cable Spreading Room continued to function after discharge of the CO_2 system.

Combustion products migrated to the Control Room and breathing apparatus was being worn by a few occupants for comfort reasons.

There was confusion regarding the emergency fire reporting phone numbers.

No water type first aid fire extinguishers were available.

There was delayed alarm to the Control Room (15 minutes).

There was delayed alarm to plant-wide personnel.

There was delayed alarm to the Athens Fire Department (49 minutes).

There were ineffective fire fighting actions.

There was a failure to utilize water on the fire until approximately 7:00 P.M.

There was a failure to follow Athens Fire Chief's advice regarding the use of water.

Plant personnel did not recognize the plant fire alarm when tripped.

The CO_2 system in the Cable Spreading Room was designed for manual operation; the manual stations were inaccessible; the system power disconnected; and there was no inspection, testing, or maintenance program for the CO_2 system.

There was a lack of adequate breathing apparatus, some of the equipment that was available was in poor condition, the recharging system was inadequate, and there was no inspection testing or maintenance program for this equipment.

There was a 15-minute delay in admitting Athens Fire Department.

The ventilation systems in the Reactor Building were inoperable from 12:45 to 4:00 P.M.

There was use of nonstandard threads on interior hose lines.

The large dry chemical cart fire extinguisher was unusable because of a broken nozzle; again a lack of inspection, testing, and maintenance procedures.

There was a lack of emergency lighting, particularly in the stairwells.

There was no effective valve inspection program.

There was a lack of a formal, qualified, in-house fire protection program.

PAST EXPERIENCES

The record is replete with similar past occurrences: Gothenburg Power Station suffered a cable fire and was shut down for one year. A cable fire occurred in a 600 MW German power station. A nuclear power station in Muhleberg, Switzerland, (1971) suffered a £ 2 million fire which put it down for seven months (this fire was started by oil under pressure but was spread by cables and unprotected openings). A control room was destroyed at a Finnish power station under construction after the fire spread through cables. There was £ 75,000 worth of damage from a fire in a cable tunnel at Battersea Power Station which contributed to a six-hour interruption of power to 15% of the Greater London Area, at Hinkley, England, in July 1966, as a result of an oil fire which spread to cables in trays and caused serious damage. In the U.S. alone we have experienced several fires: at Peach Bottom Unit 1 a cable fire was started during construction; at San Onofre Unit 1 there were two cable fires in 1968; at Nine Mile Point Unit 1 a fire occurred during start-up testing; at Indian Point Unit 2 there was a fire involving wood scaffolding which spread to cable trays; at Quad Cities Unit 2 there was a fire in electrical trays; at Beaver Valley Unit 1 a fire occurred at a motor control center; at Oconee Unit 1 two fires have occurred; at Oconee Unit 2 an oil fire charred some cables; at Salem Unit 1 a welding operation initiated fire in a cable tray; and at Salem Unit 2 construction activities ignited wood forms and burned cables. The construction stage of a nuclear power plant has long been recognized as its most vulnerable period with regard to the probability of fire. This very point was discussed in Zurich at the Fourth International Fire Protection Seminar on Fire Protection in Nuclear Power Plants.

It is interesting to note that there was concern regarding the use of water at Browns Ferry during the fire as well as concern in the consideration of its use in automatic protection systems to upgrade the facility after the fire. Yet the record indicates some interesting experiences. SCHADEN SPIEGEL reporting on a fire in a nuclear power plant indicates that "...it was only possible to clean the building by means of water, adding a wetting agent, and by the subsequent application of high-pressure steam."

A fire which occurred in 1967 at Tokai Mura Unit 1 in Japan is of interest. Due to failure of a cock in a strainer assembly in the reactor building, a major quantity of oil sprayed out when a strainer was being changed, and was ignited by steam pipes at 360°C. The sprinkler system put out the fire in four minutes. The reactor was not damaged.

The cable fire which occurred at DESY, near Hamburg, on May 6, 1975, was similar to the Browns Ferry incident. There was an absence of fixed automatic fire suppression equipment and plant brigade personnel were unable to fight the fire because of smoke conditions.

MAJOR CAUSE OF EXTENT OF FIRE

In the judgement of this writer, the major cause of this disaster was the lack of an adequate fire protection program and the lack of qualified fire protection engineering staff. The term disaster in this sense is used primarily in relation to the magnitude of the direct and indirect losses including business interruption losses.

A candle was the cause of ignition, but it is well known that the CAUSE OF THE FIRE IS ONE THING, THE CAUSE OF THE DISASTER IS ANOTHER.

The previous list of related factors simply identifies and emphasizes the major defect of not having a qualified fire protection program with qualified, fire protection staffing. The items on the list are but symptoms of the major problem which existed prior to March 22, 1975. While close analysis of the factors related to the incident as presented in the previous list may indicate that correction of even one or some of these deficiencies may have prevented the March 22nd fire, it is clear that these corrections alone would not have provided adequate fire protection. After review of the incident, two visits to the facility, and other experiences gained over the past year and a half, it is my judgement that the potential for disaster existed from other potential sources of ignition. I believe that the fire protection knowledge available at the time of the Browns Ferry design, its construction, and its operation was never adequately applied. There is a lesson to be learned from the Browns Ferry story in that there is again the need to provide the basic, fundamental concepts of fire protection which have been known and understood within the fire protection engineering fraternity for some time; i.e., that those responsible for design,

design review, operation, and operating review of such facilities must provide qualified input from both reactor safety and fire protection disciplines. In the case of a facility the size and complexity of Browns Ferry it is essential that fire protection be designed into the facility rather than be provided as an "add-on". Again, I would refer you to the Fourth International Fire Protection Seminar held at Zurich on Fire Protection in Nuclear Power Plants and Dr. I. Stromdahl's paper.

Following the Browns Ferry Fire, there was considerable discussion by some regarding the need for more standards, more codes, more criteria for such facilities. Such an approach hardly appears justified. In the case of Browns Ferry, existing fire protection standards, codes, and criteria were not followed. Thus, the solution would hardly appear to be the development of more standards. Rather, the solution requires the application of existing and adequate fire protection engineering principles by qualified fire protection engineers.

Examination of codes and standards writing reveals an effort to provide specific details to ensure proper design of the facility. In many cases these specific design details are even provided in "design criteria" or "conceptional" documents. Other standards writers all at the same time attempting to achieve proper design by defining functional goals. The result is usually a compromise or mixture which leads to confusion and misunderstanding on the part of design personnel who are not experienced or qualified in fire protection engineering. At the Fourth Internationa Fire Protection Seminar in Zurich on Fire Protection in Nuclear Power Plants, J. E. Troutman of the Factory Insurance Association stated that the guideline entitled "Nuclear Energy Property Insurance Association - Mutual Atomic Energy Reinsurance Pool Basic Fire Protection for Nuclear Power Plants" is intended only as an outline for use by experienced fire protection engineers having some nuclear experience.

Browns Ferry was a hard lesson for many. The Tennessee Valley Authority has since supplemented their staff with two fire protection engineers. The Nuclear Regulatory Commission has one fire protection engineer on its staff. Both the Nuclear Regulatory Commission and the Tennessee Valley Authority have provided additional training in fire protection for other staff members.

The post fire upgrading of the Browns Ferry Nuclear Plant calls for three basic design considerations; first, the use of administrative actions to minimize the occurrence of fire; second, the use of isolation to prevent a fire from damaging redundant safety equipment; and third, the provision of a means to detect and control or extinguish a fire quickly. The plan for accomplishment of these considerations includes the following:

The completion of a plant-wide analysis to identify combustible fuel loadings, maximum potential fire severity, and the need for additional fire protection features to insure the protection of safe shutdown. An impairment analysis was a part of this overall study.

Protection of all exposed cables in the secondary containment area of the Reactor Building, the Cable Spreading Room, Diesel Generator Building, the Water Pumping Station, and the Pumping Station Cable Tunnel by the use of a fire retardant coating (Flameastic 71A).

Provision of a pre-action sprinkler system in the Reactor Building, over the cable trays designed for an application rate of 12.2mm/min (0.3 gpm/sq ft) for a 465 sq meter (5,000 sq ft) area.

Provision of automatic water spray systems for a few selected high density cable tray areas with a designed water application rate of 12.2mm/min (0.3 gpm/

sq ft) of projected area.

Note: The analysis for the requirement of the water spray protection in the above-listed items was completed without consideration of the fire retardant coating, thus, it is considered conservative.

Expansion of the smoke and heat detection systems throughout the plant.

Provision of a diesel-driven fire pump.

Provision of additional interior hose lines.

Removal of the urethane foam firestops and replacement with a silicone seal which has been tested and proved adequate for the purpose.

Provision of additional fire doors and fire separations in critical areas.

Revision of the training program for Fire Brigade Leaders and Members.

Provision of periodic drills at the plant site.

Provision of a formal indoctrination program for all plant personnel.

Provision of upgraded cutting, welding, and hot work permit controls.

Procedures for the control of temporary combustible loading.

Improved procedures for the control of all fire protection related inspection, testing, and maintenance.

Procedures for outside or independent fire protection review.

Organizational changes which include the provision of professional fire protection engineers, and a Fire Protection and Prevention Board to coordinate engineering, design, and operation.

Modifications to cable routings to provide more adequate spatial separation.

Changes to the electric power system to improve isolation.

Provision of dampers and improved selectivity in sectionalizing ventilation.

Provision of a back-up remote manual sprinkler system in the Cable Spreading Room.

Increased number of self-contained breathing apparatus and upgraded recharging capacity.

Addition of a portable Radio Emergency Command Net.

Additional emergency lighting.

Modifications to detection system's power supply.

Replacement of nonapproved or nonlisted equipment.

Additions to the Technical Specifications.

The new specifications incorporate limiting conditions for operation for (1) operability of the high pressure fire pumps and unit shutdown requirements if the system does not meet these limits, (2) minimum system pressure and flow limits, (3) minimum storage limits for CO_2 in the storage tank, (4) limits for CO_2 system operability and unit shutdown requirements if the system does not meet these limits, (5) limits on the minimum fire detection system operability and requirements for a fire watch if the detector system limits are not met, (6) requirements for a roving fire watch during the period between restart and the first refueling, (7) requirements for an annual independent fire protection and loss prevention inspection, (8) requirements for an inspection and audit by an outside qualified fire consultant every three *years, and (9) requirements for the minimum in-plant fire protection organization and duties to be maintained.*

Surveillance requirements are also incorporated in the specifications to require periodic testing and inspection of the fire protection systems and the fire detection systems that must be performed at specified time intervals to ensure that the fire protection systems are operable. The majority of the surveillance intervals are consistent with the NFPA code. The other intervals were determined based on the as-built plant systems and unique requirements for the Browns Ferry Plant.

Requirements for a full pre-operational retest program.

In addition to these modifications at Browns Ferry, the Nuclear Regulatory Commission has recently completed development and publication of design guidelines for fire protection in nuclear power plants, Ref. U.S. Nuclear Regulatory Commission Standard Review Plan Section 9.5.1 Fire Protection System, Branch Technical Position APCSB 9.5-1 Guidelines for Fire Protection for Nuclear Power Plants. This document does include recognition of the requirement for management participation in support of a qualified fire protection program having qualified staff. These guidelines apply to new plants, however, an Appendix has been published which applies to all other plants.

The degree of success, however, depends more strongly upon the degree of management interest in establishing a viable and effective fire protection program. For it has been recognized that the single most important element in an "Improved Risk" program is management interest. Equipment alone does not provide fire protection; the occupancies must be controlled; systems must be inspected, tested and maintained; personnel must be trained; procedures must be reviewed; loss potential audits must be completed regularly; and other elements essential to a complete fire protection program along with the proper management system providing the appropriate checks and balances necessary to insure its continuous effective operation must be present.

The lessons of Browns Ferry should not be new to those with extensive industrial experience, but the Browns Ferry story is an oft repeated example of preventable neglect. So, what is the moral of this story--I believe we must redouble our efforts with regard to selling our profession to management to promote, first, the desire to receive the fire protection input and second, to provide management with the proper fire protection input to allow their decision-making procedures to be made with consideration of all the issues and, thus, achieve the balance which is necessary for overall nuclear safety. It is imperative that the fire protection provided ensure public safety and protect against economic loss, both direct and indirect. A fire in a nuclear power facility can produce strong public reaction, even though such a fire may have presented no risk to safe shutdown. This was recognized by J. R. Corcoran in his talk at the Fourth International Fire Protection Seminar in Zurich on Fire Protection in Nuclear Power Plants. Such public reaction can result in significant indirect losses. For Browns Ferry these losses would include the expenses associated with the Joint Committee on Atomic Energy Hearings, the Advisory Committee on Reactor Safeguards Hearings and the Licensing Board Hearings.

Other indirect losses would include all expenses associated with the recovery operation incurred by the Tennessee Valley Authority and the Nuclear Regulatory Commission. The recovery effort at the Browns Ferry Plant for Units 1 and 2 consumed the efforts of several hundred people for a period of over 18 months or more and most of that time involved extended work periods. If overtime is included, the manpower in this effort may exceed 1000 man years.

Also, in addition to the $200 million dollar loss in the cost of purchasing electric generation capacity previously mentioned, there is a loss of a $1 billion capital investment that has not produced any return for 18 months. A 10% return on this investment for 18 months would amount to over $170 million. Thus, estimates of the total indirect losses associated with this fire are on the order of approaching One-Half Billion Dollars. There is also the intangible loss associated with damage to the image and future of the nuclear power industry.

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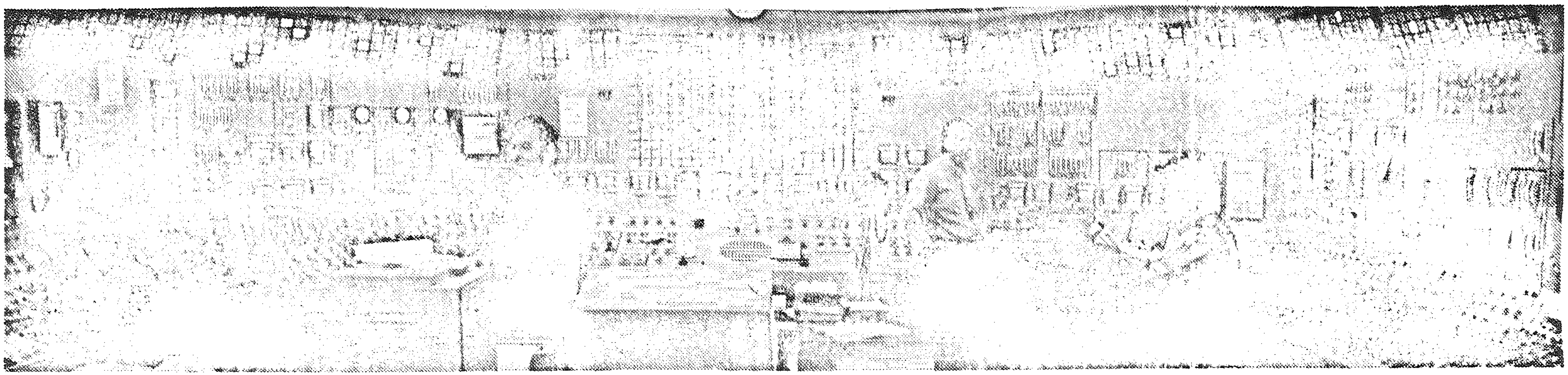
LIST OF FIGURES

LIST OF FIGURES (cont.)



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The Frightful Log of a Nuclear Near-Miss

Candle Starts a Fire, Shakes Faith in Safety Systems at Power Plants

By William J. Lanouette

IT BEGAN with a candle, which accidentally lit some flammable insulation, burned some cables, and nearly caused one of the most serious nuclear-power plant accidents possible —a "meltdown" of the heat-producing, radioactive core.

From the Browns Ferry Nuclear Plant near Athens, Ala., where the seven-hour blaze began, warnings and misinformation fanned through the emergency network of the Tennessee Valley Authority (TVA), the plant's owner, to state and Federal officials in nearby cities. One official recalls reports that the plant's reactors were "wiped out" and that the only way to keep the radioactive fuel from melting was "to bring in river water and circulate it to and from ditches for cooling."

That's history now, although the March 22 fire sparked a controversy about the safety and reliability of nuclear power that is sure to smolder for years. And while some public officials and nuclear-industry executives were

chemical extinguisher, and then another, neither of which put out the fire. . . . In the past, on three or four occasions, I have had fires started by the candle . . . which [were] readily extinguished."

Another electrician ran out to a guard post nearby and returned with a fire extinguisher. This alerted the guard to report the fire by telephone. But he dialed the wrong number. The person who answered in turn dialed the control room, warning the unit-one operator about the fire. In the control room, an assistant shift engineer flipped on the fire alarm. It was 12:34 p.m.

Reinforcements

The assistant shift engineer then grabbe
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were always easy for me to extinguish

FIGURE 1

JOURNALISM FOLLOWING BROWNS FERRY FIRE

supervisor recalls, the control room "was full of smoke and the operators were wearing Scott Air Paks." Adds an assistant shift engineer: "I saw people forcing rags in holes under the electrical operator's desk. CO2 was coming through them."

Meanwhile, the fire continued to run along the cable trays, in the cable-spreading room, and farther into the reactor building. In the cable-spreading room, the plant's fire fighters couldn't turn on an overhead CO2 spray system because metal construction plates, in which the system had been shipped to the plant, could not be removed without a screwdriver. "A wheeled dry-chemical cart had been brought . . . [in] but its nozzle was
'stant shift en-

ıst something
:inued. "I got
ıd passed out
ing on top of
I didn't know
now I got there. I rested a bit and, since the first-aid room was locked . . . went

the atmosphere. Some air samples were taken at a meteorological tower near the plant beginning at 5:14 p.m., but at 6:05 p.m. the tower was abandoned as smoke headed toward the tower. Other samples showed that radiation levels were within NRC limits.

At 5:45 p.m. TVA's health-laboratory director reported that environmental air sampling for possible radiation had started in Athens, 10 miles northeast of the plant; in Hillsboro, 10 miles southwest; and in Rogersville, 25 miles northwest. "The sampler at Decatur, Ala., [20 miles southeast] was thought to be inoperable," the NRC staff reported, and ". . . at 7:50 p.m. there was no air sampler available at Decatur," a city of 40,000 directly downwind from the plant. No radiological samplers were available at Decatur that evening, the NRC notes, although an air-pollution sampler was set up there at 9 p.m. At 8:37 p.m. the aircraft-warning lights on the plant's 600-foot stack went out.

Delays in Reporting

NRC investigators also discovered

BROWNS FERRY NUCLEAR PLANT

TENNESSEE VALLEY AUTHORITY
Knoxville, Tennessee 37902
June 1970

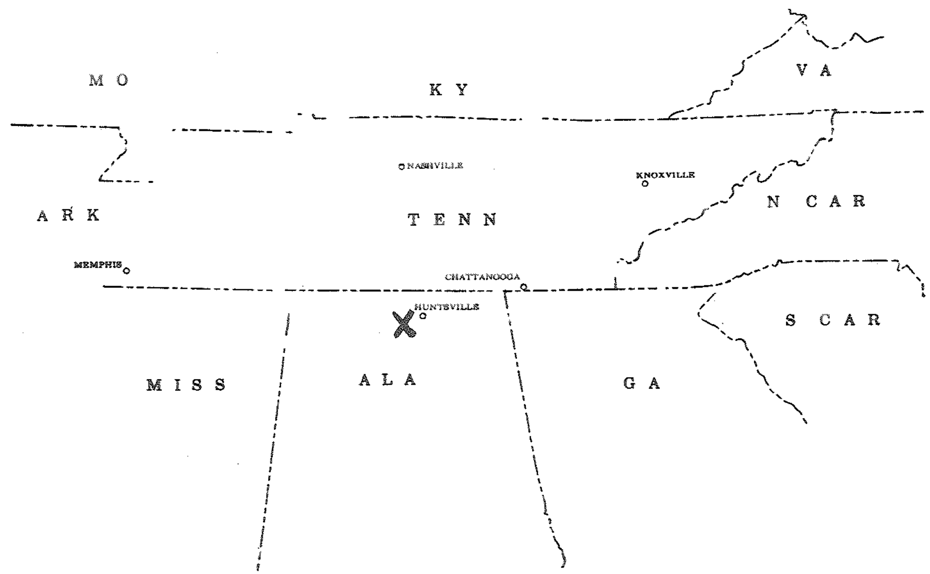

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FIGURE 2
BROWNS FERRY NUCLEAR PLANT LOCATION

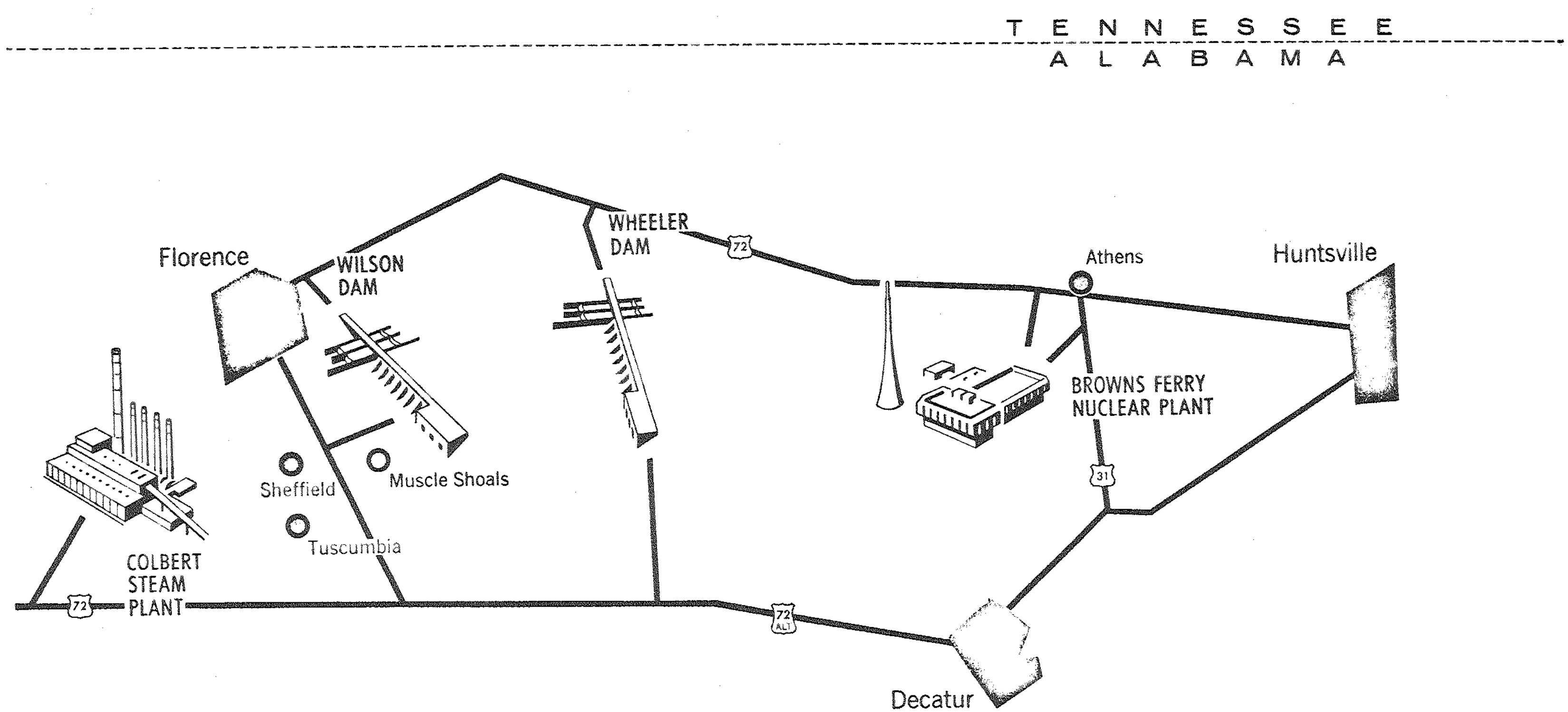


FIGURE 3
BROWNS FERRY NUCLEAR PLANT LOCATION

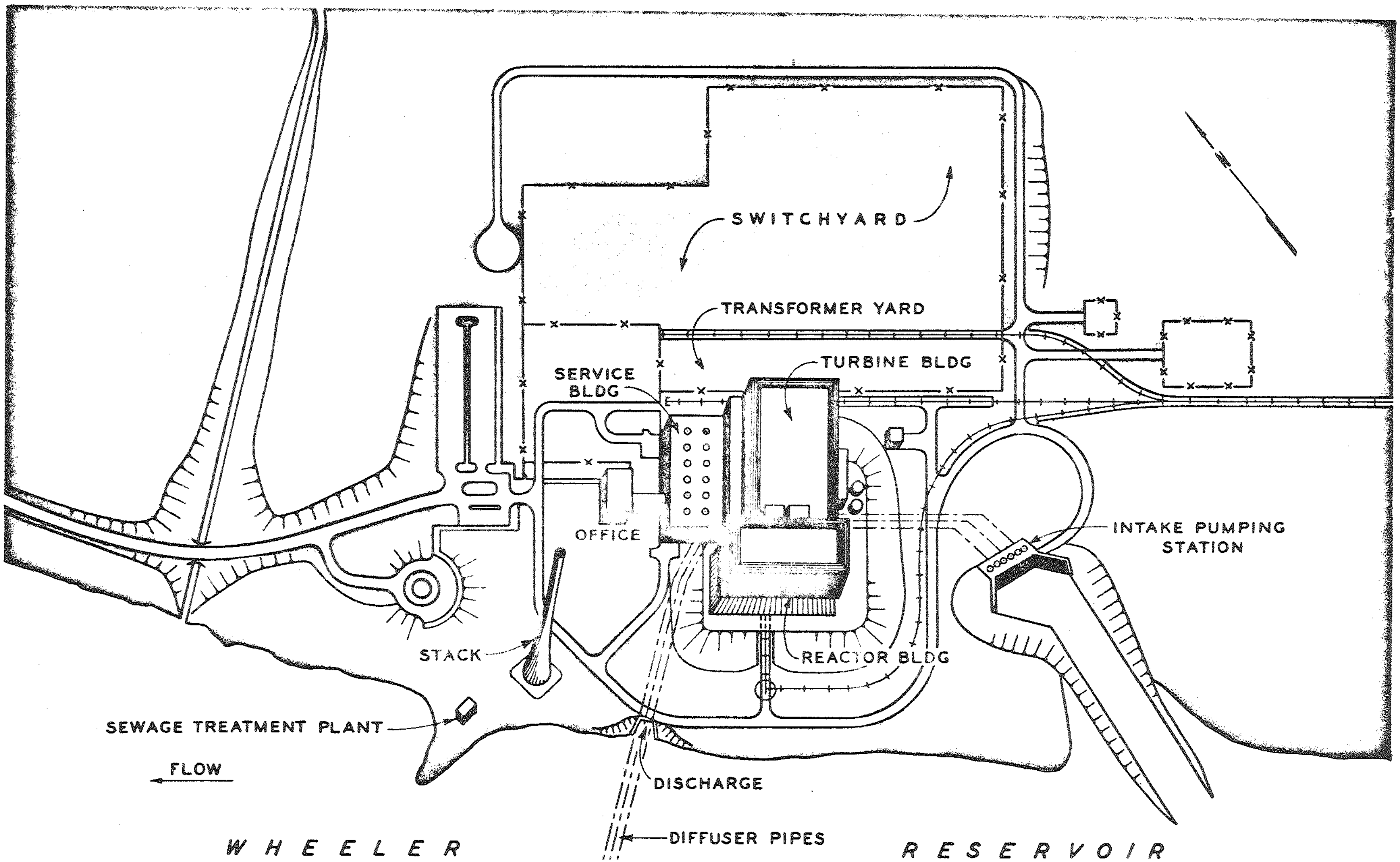


FIGURE 4
LAYOUT OF BROWNS FERRY NUCLEAR PLANT

FIGURE 5
BROWNS FERRY NUCLEAR PLANT LOOKING WEST

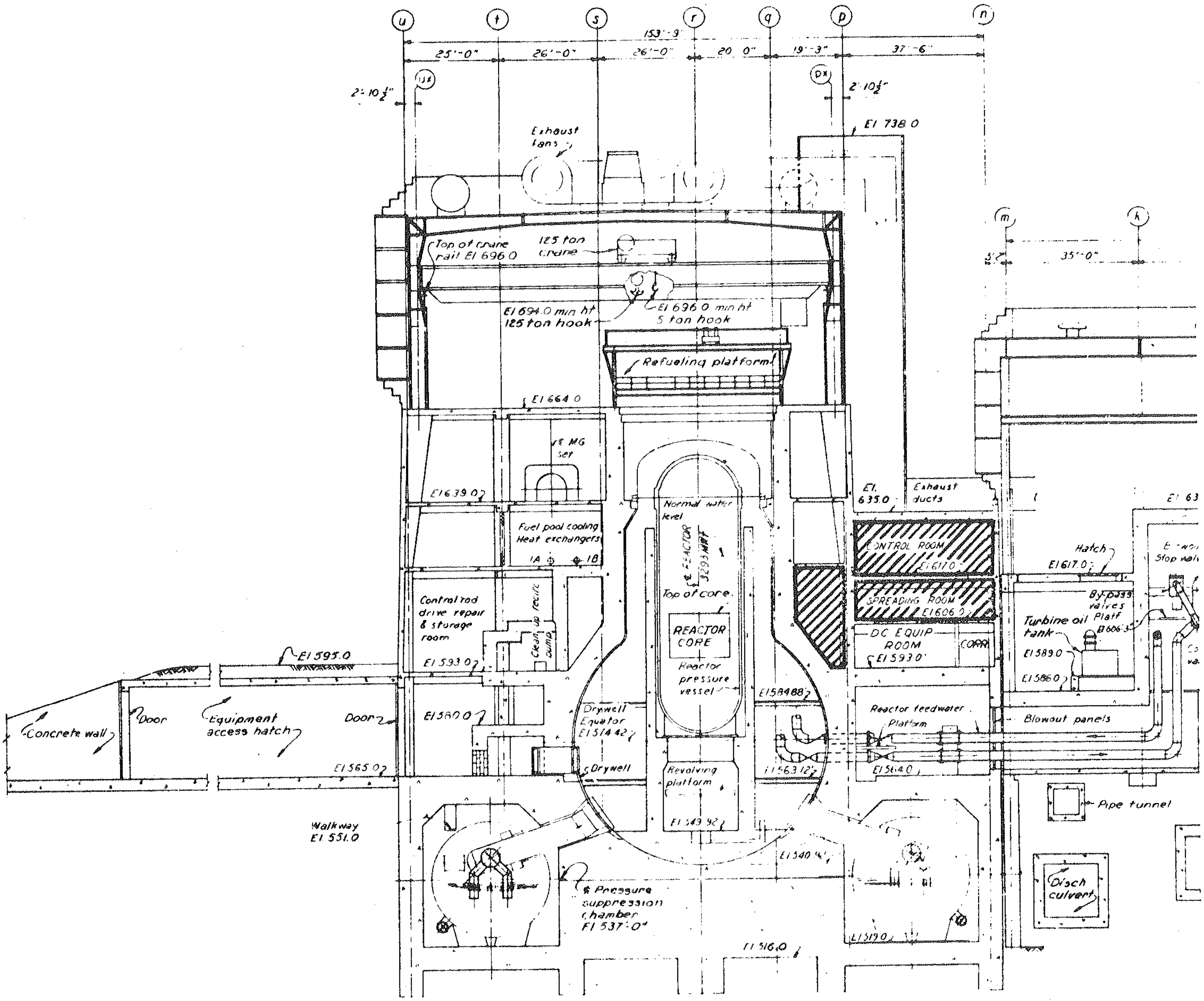
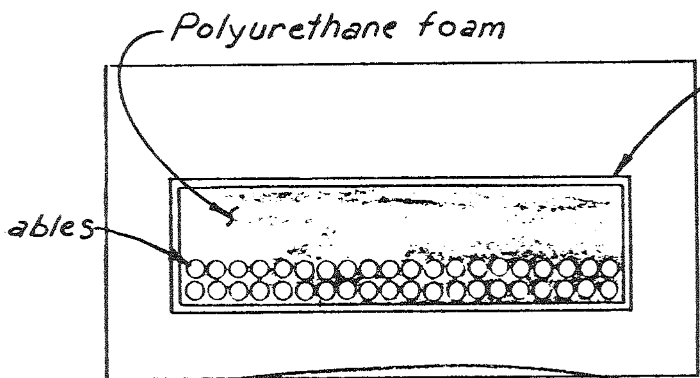


FIGURE 7
VERTICAL CROSS SECTION REACTOR BUILDING,
CONTROL ROOM AND CABLE SPREADING ROOM

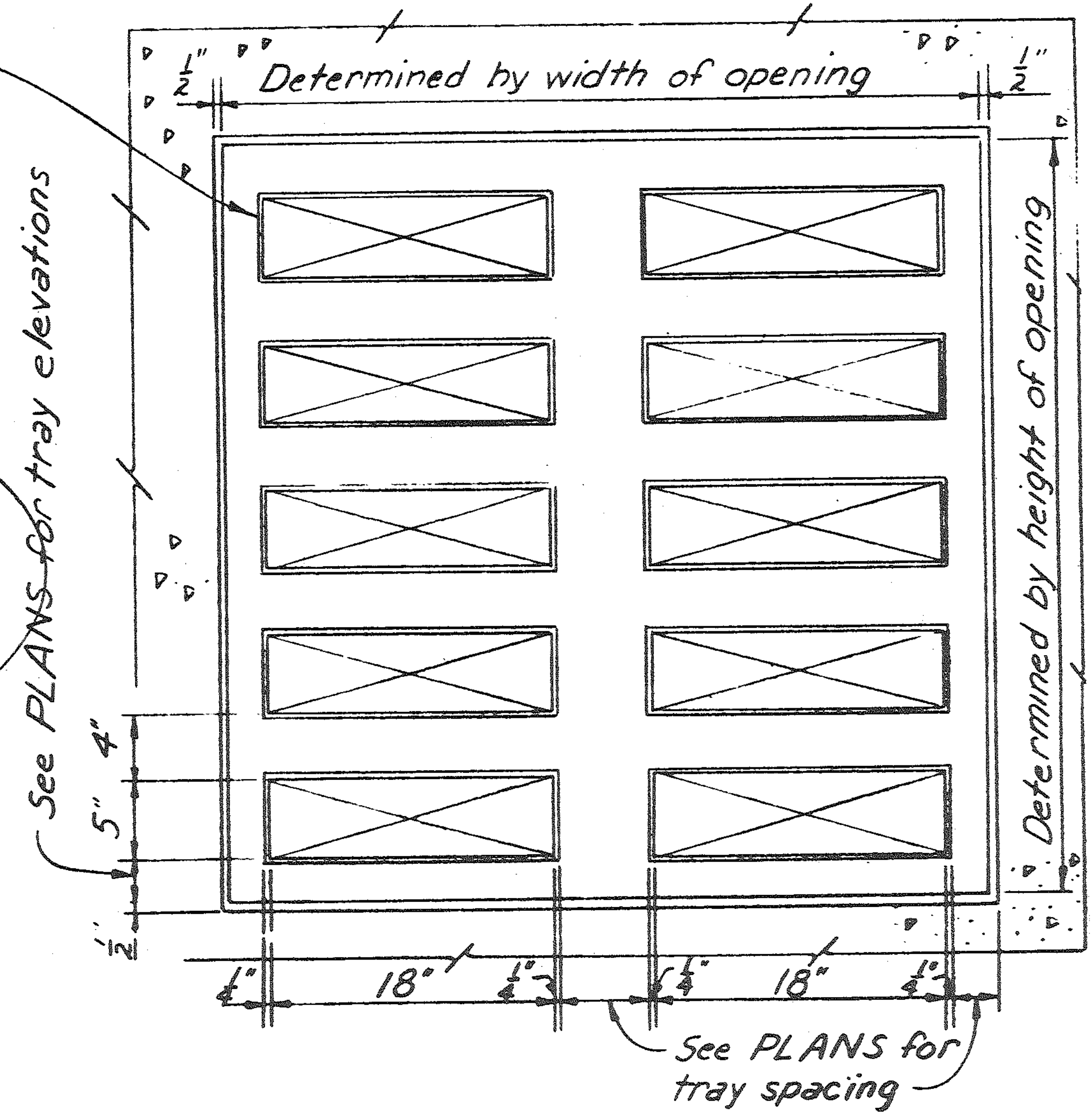
47W200-8 R2



NOTES:

A. When all cables have been installed through cable sleeve, seal the remaining opening and voids with 6" $\pm$ of Urethane foam or equal before applying flame proofing compound, Flamemastic 71A or equal.

B. Apply approximately 1/8" to 1/4" of flame proofing compound on the steel sleeve and on both top and bottom of the tray and cables for 12" on both sides of the barrier.



FRONT ELEVATION
Scale: 1" = 1'-0"

FIGURE 8
FRONT ELEVATION OF TYPICAL WALL CABLE
TRAY PENETRATION

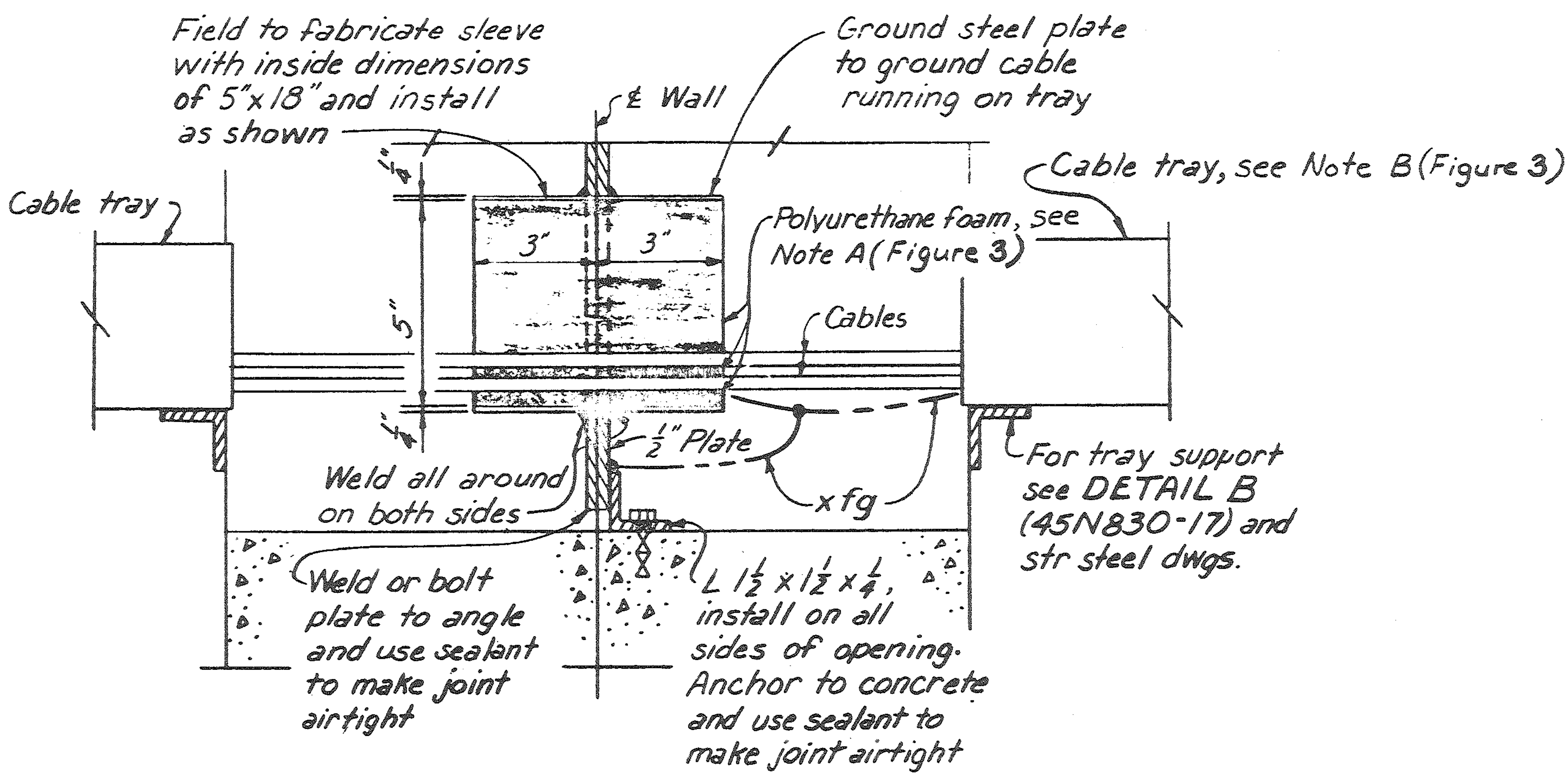
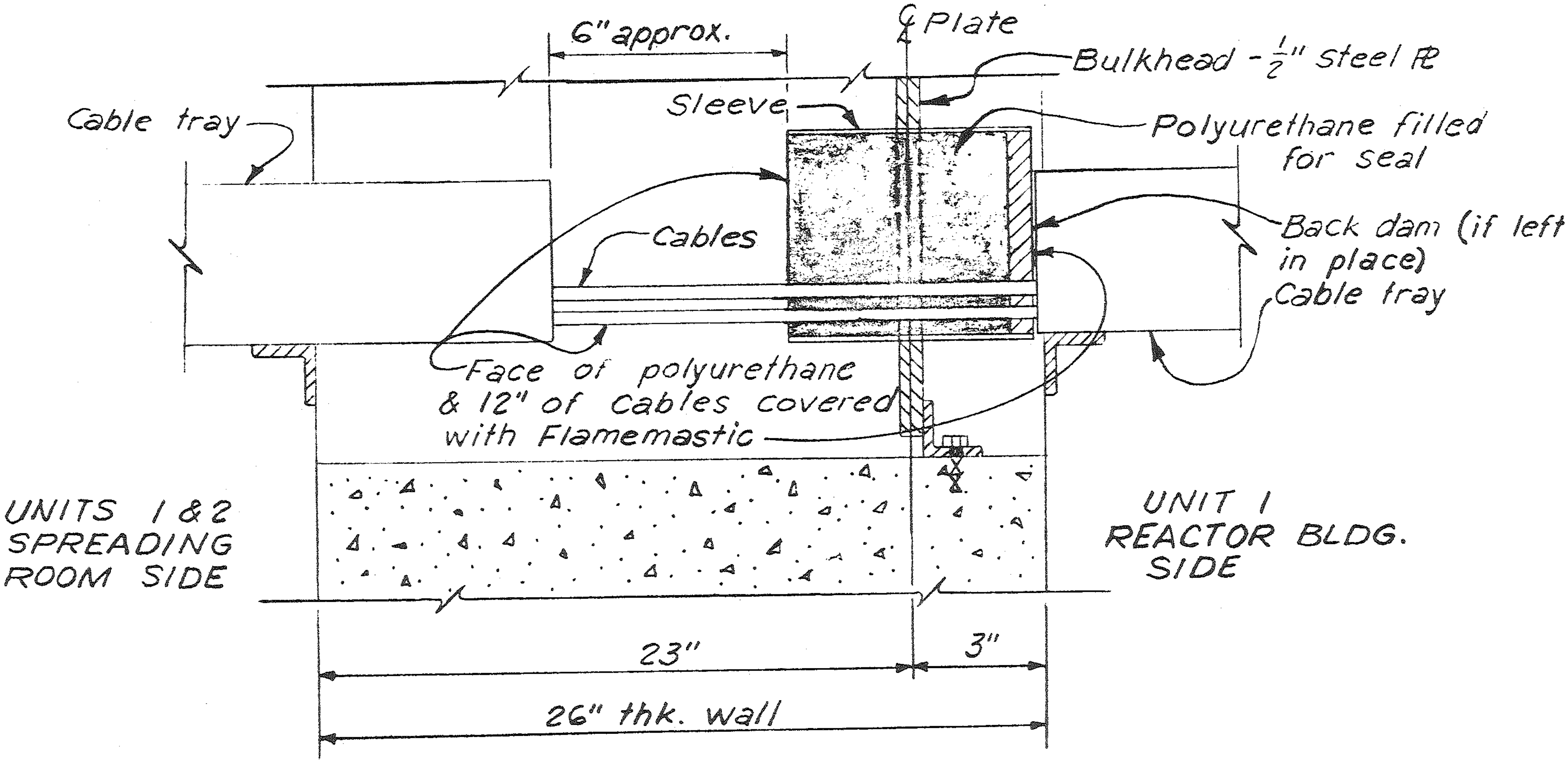


FIGURE 9
SIDE VIEW OF WALL CABLE TRAY PENETRATION DIFFERENTIAL PRESSURE SEAL AND FIRE-STOP DESIGN

NOTE: FIRE STARTED IN SECOND PENETRATION FROM BOTTOM - TRAY VE



PARTIAL CROSS SECTION OF PENETRATIONS (TO SHOW BULKHEAD LOCATION IN WALL AS CONSTRUCTED)

FIGURE 10
SIDE VIEW OF WALL CABLE TRAY PENETRATION DIFFERENTIAL PRESSURE SEAL AND FIRESTOP AS INSTALLED

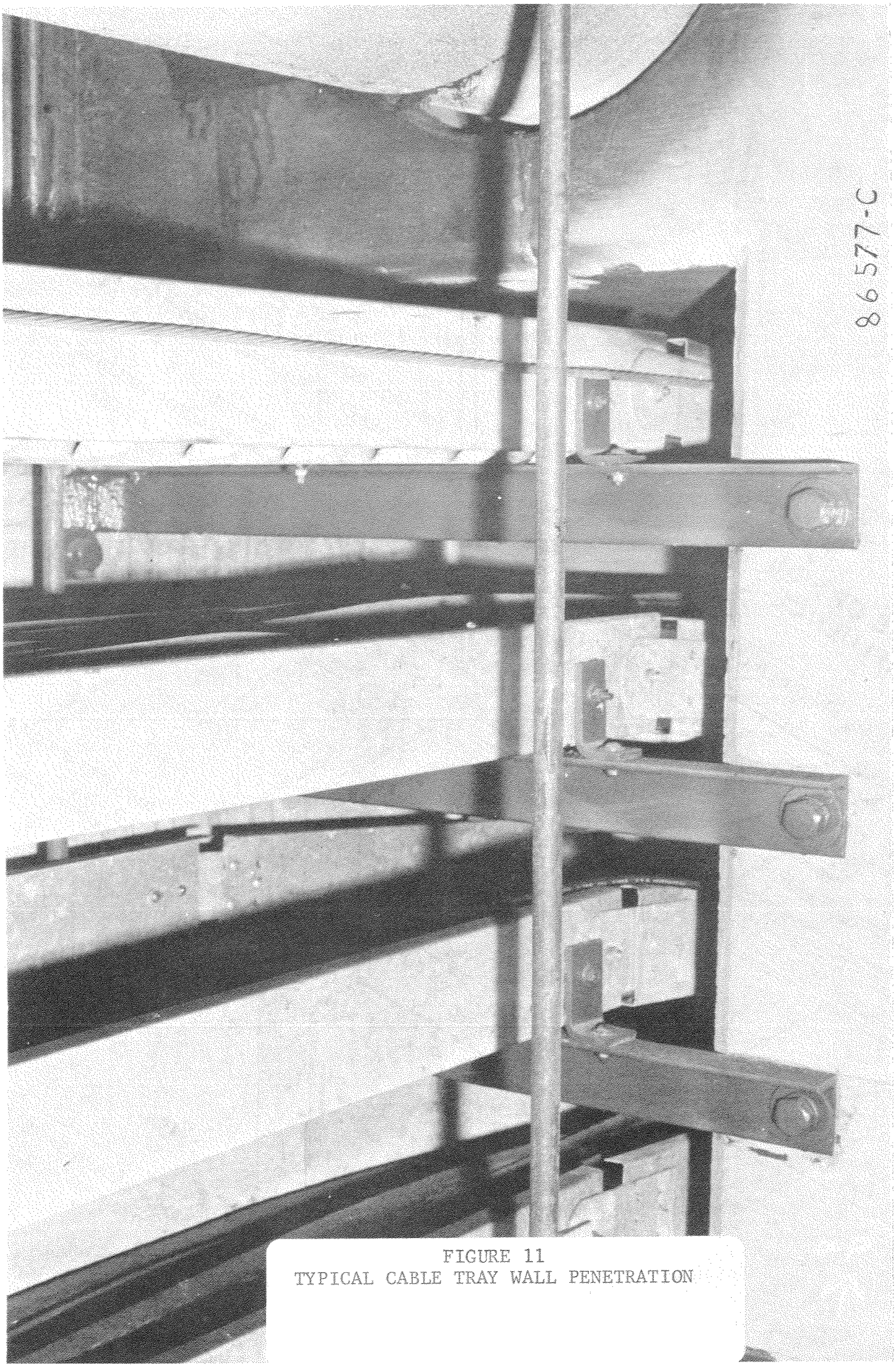


FIGURE 11
TYPICAL CABLE TRAY WALL PENETRATION

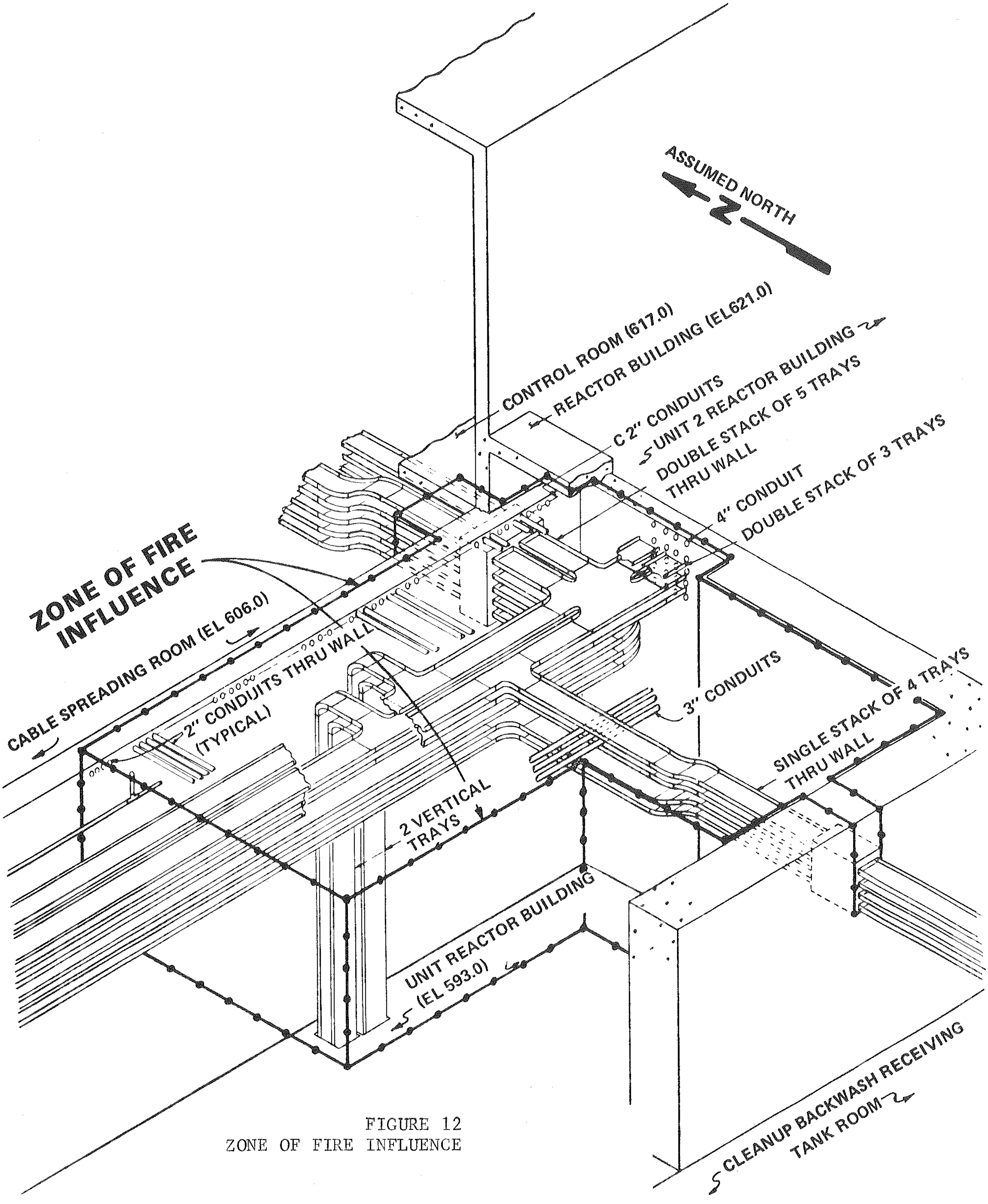


FIGURE 12
ZONE OF FIRE INFLUENCE

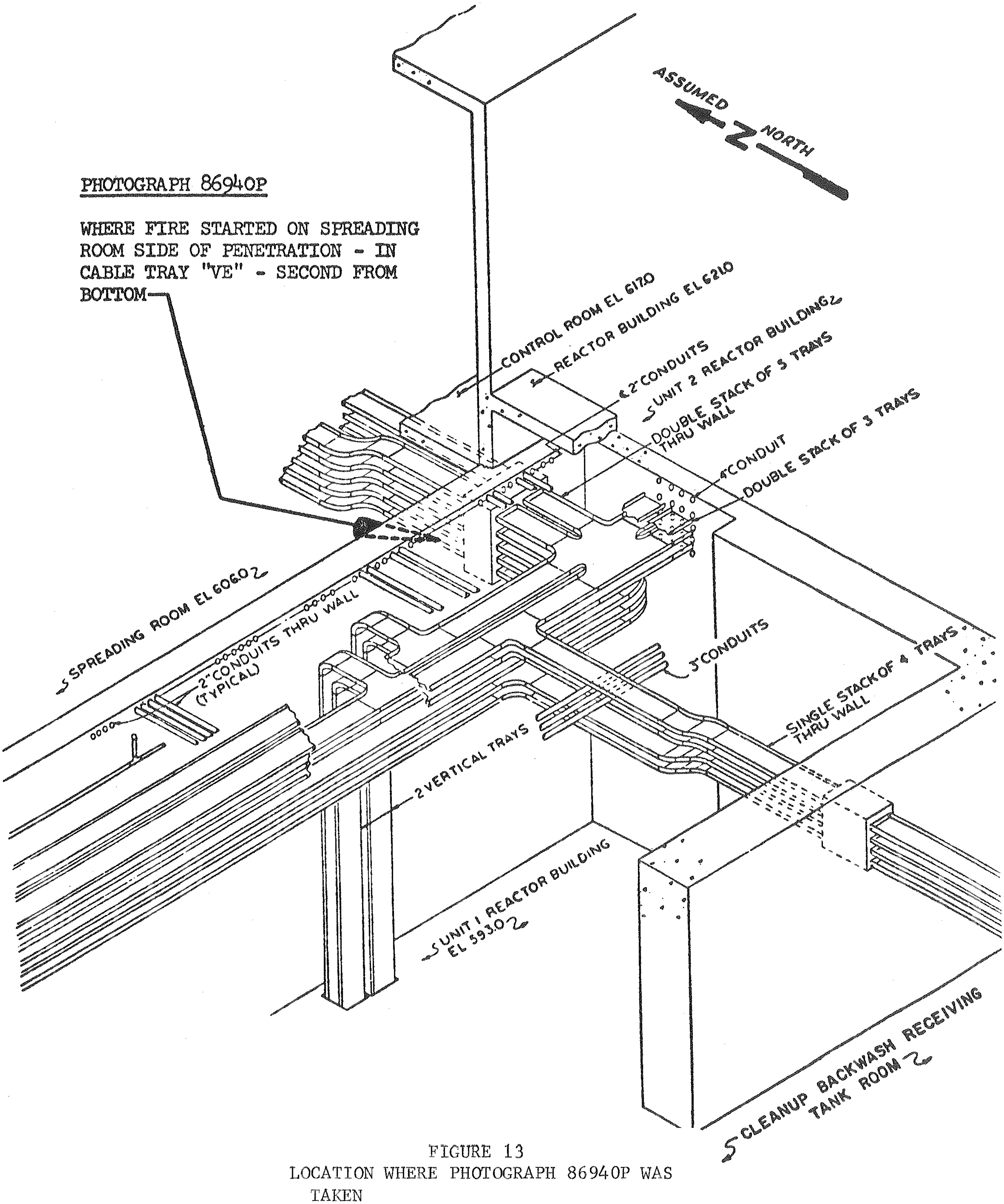


FIGURE 13
LOCATION WHERE PHOTOGRAPH 86940P WAS TAKEN

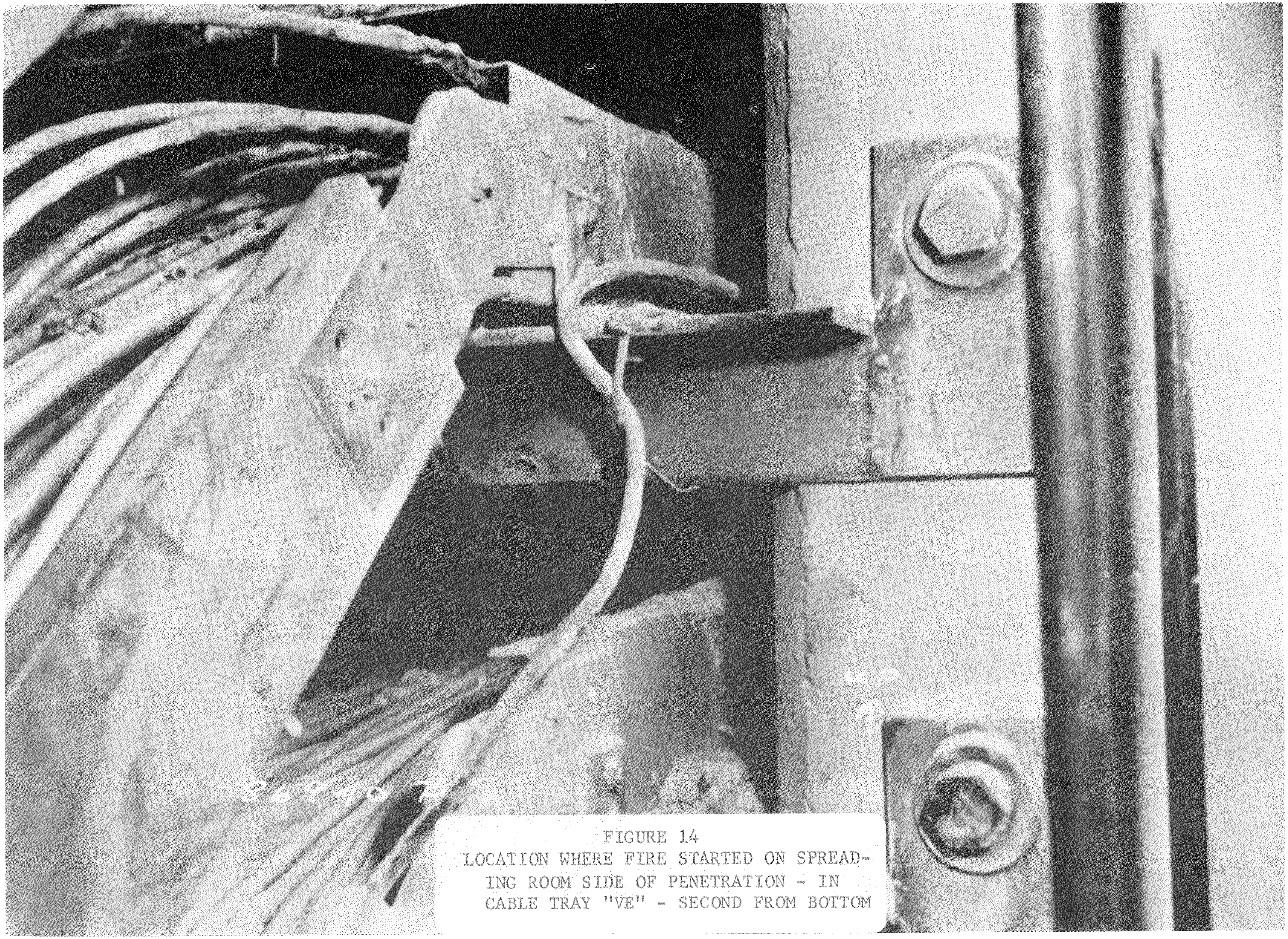


FIGURE 14
LOCATION WHERE FIRE STARTED ON SPREADING ROOM SIDE OF PENETRATION - IN CABLE TRAY "VE" - SECOND FROM BOTTOM

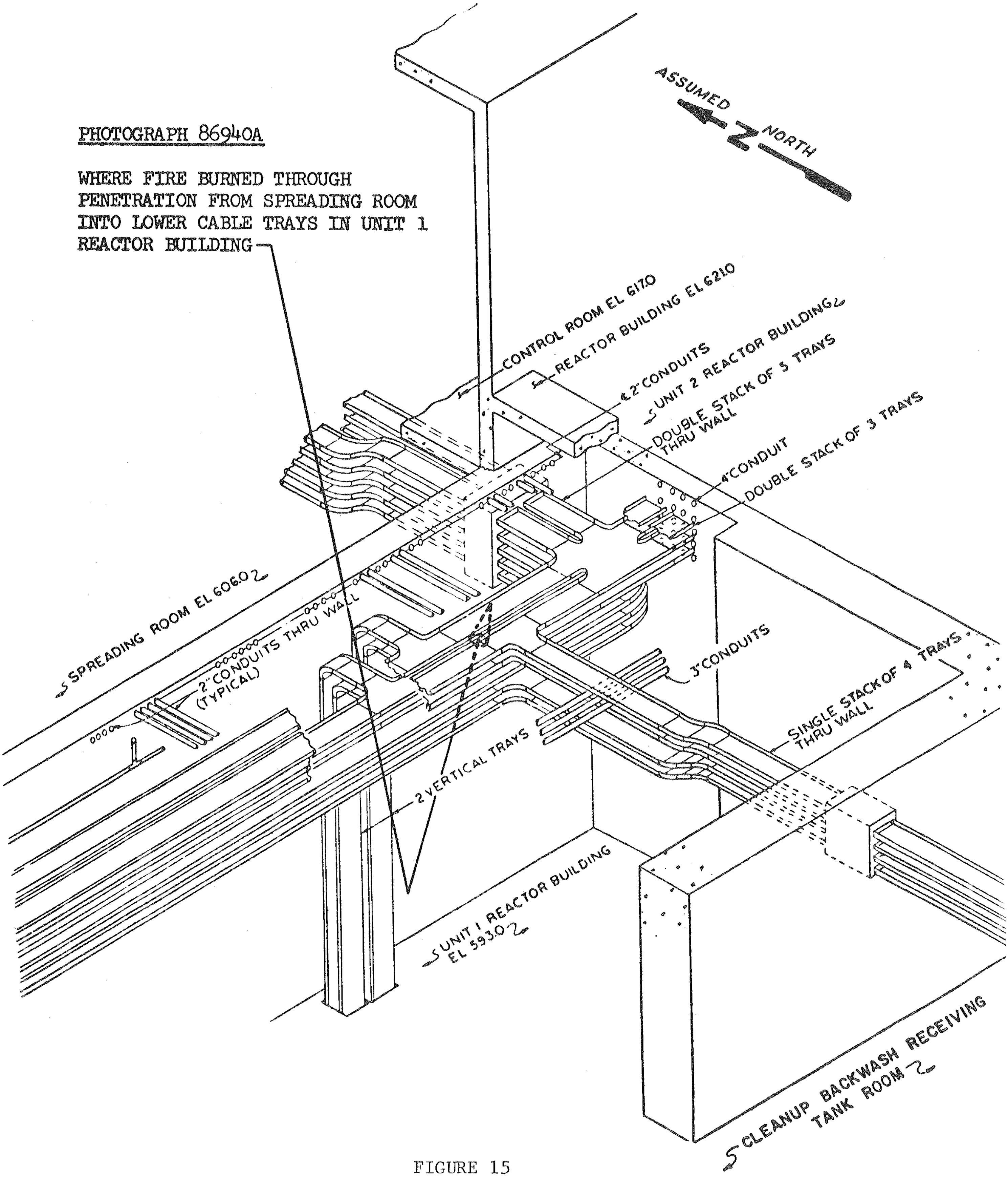


FIGURE 15
LOCATION WHERE PHOTOGRAPH 86940A WAS TAKEN

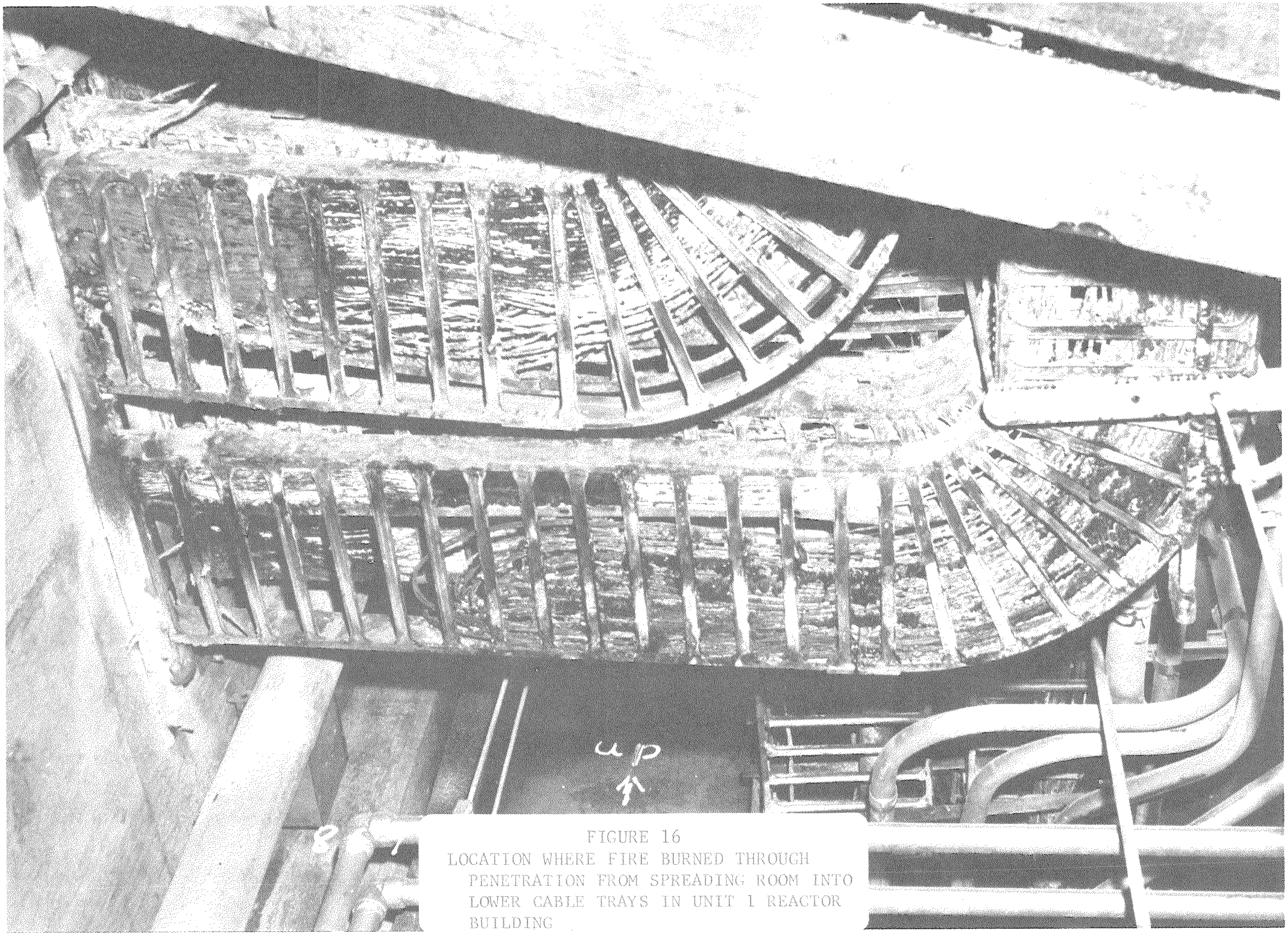


FIGURE 16
LOCATION WHERE FIRE BURNED THROUGH PENETRATION FROM SPREADING ROOM INTO LOWER CABLE TRAYS IN UNIT 1 REACTOR BUILDING

PHOTOGRAPH 67P1991

GENERAL VIEW OF FIRE DAMAGE IN NORTHEAST CORNER OF REACTOR BUILDING - SHOWS EXTENT OF FIRE PROPAGATION DOWNWARD IN VERTICAL TRAYS

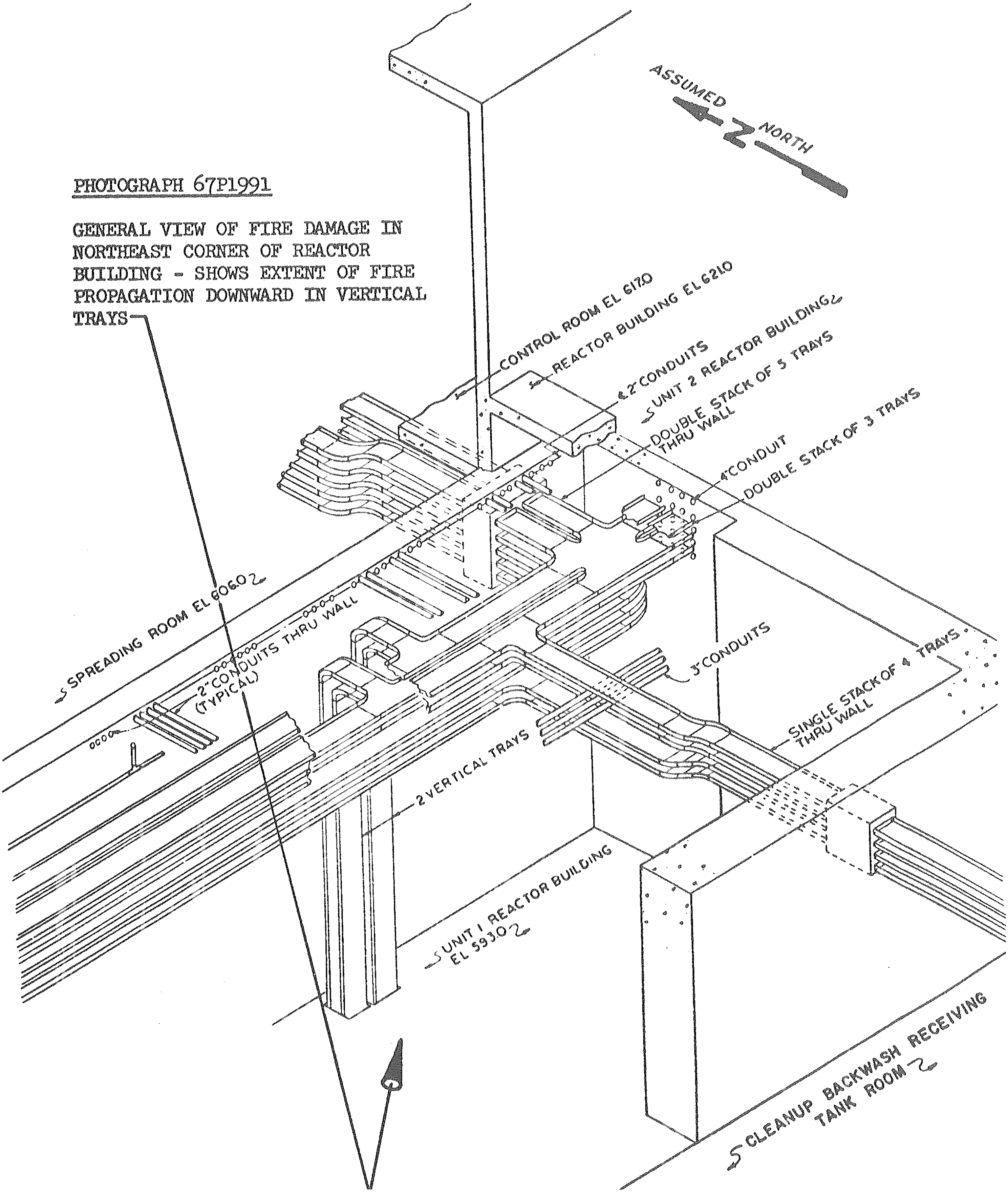


FIGURE 17
LOCATION WHERE PHOTOGRAPH 67P1991 WAS TAKEN

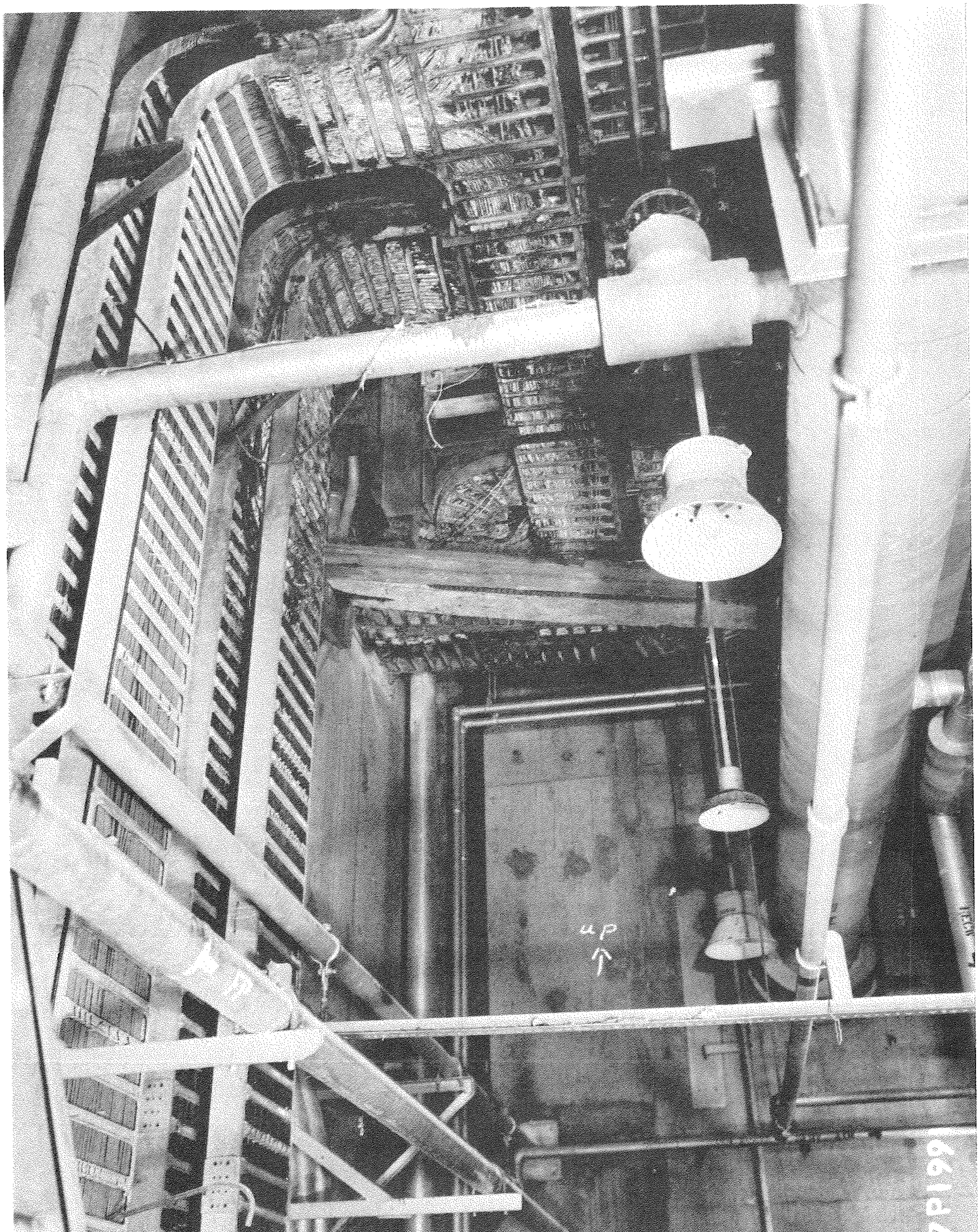


FIGURE 18
FIRE DAMAGE IN NORTHEAST CORNER OF REACTOR BUILDING - SHOWS EXTENT OF FIRE PROPAGATION DOWNWARD IN VERTICAL TRAYS

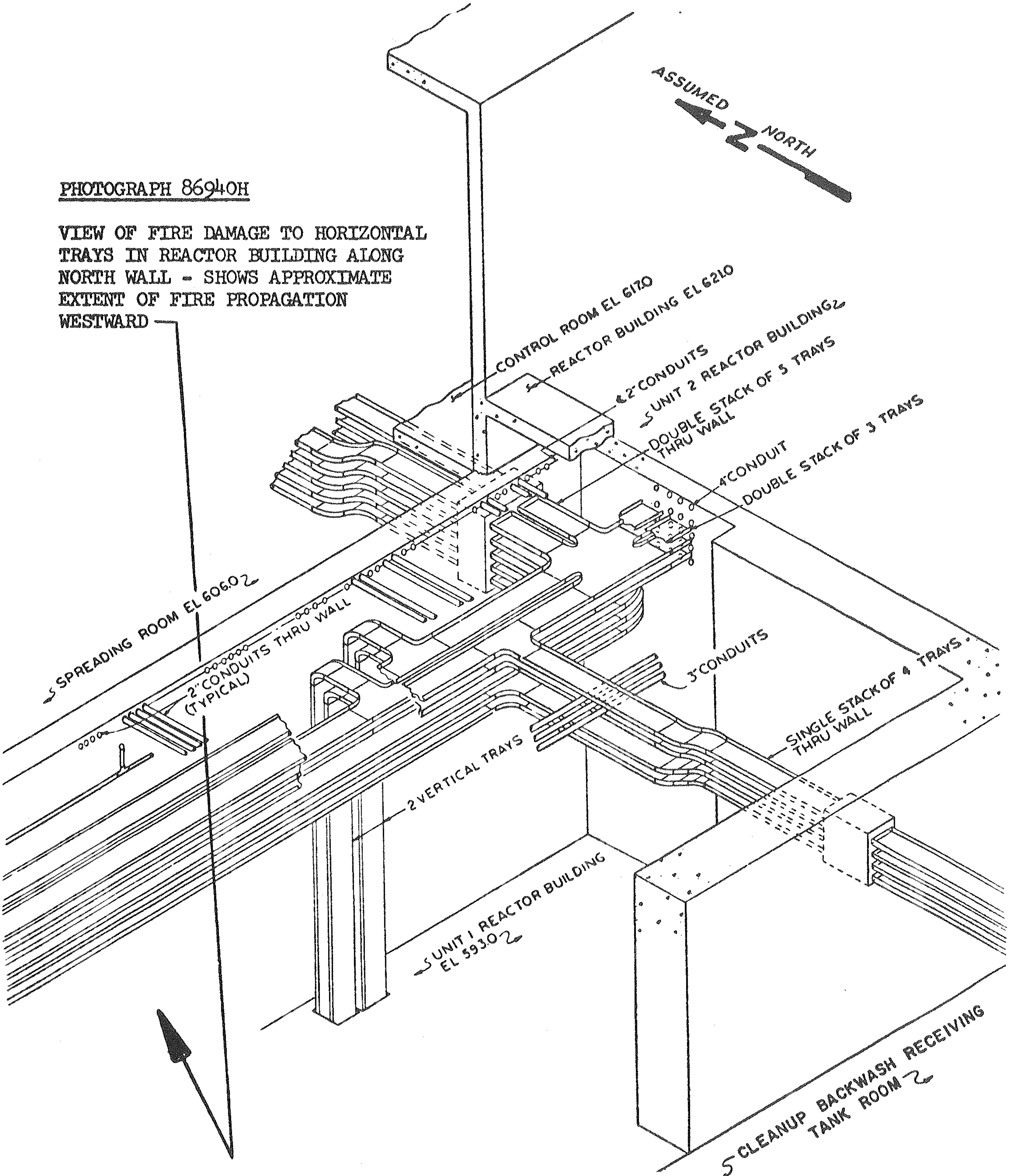


FIGURE 19
LOCATION WHERE PHOTOGRAPH 86940H WAS TAKEN

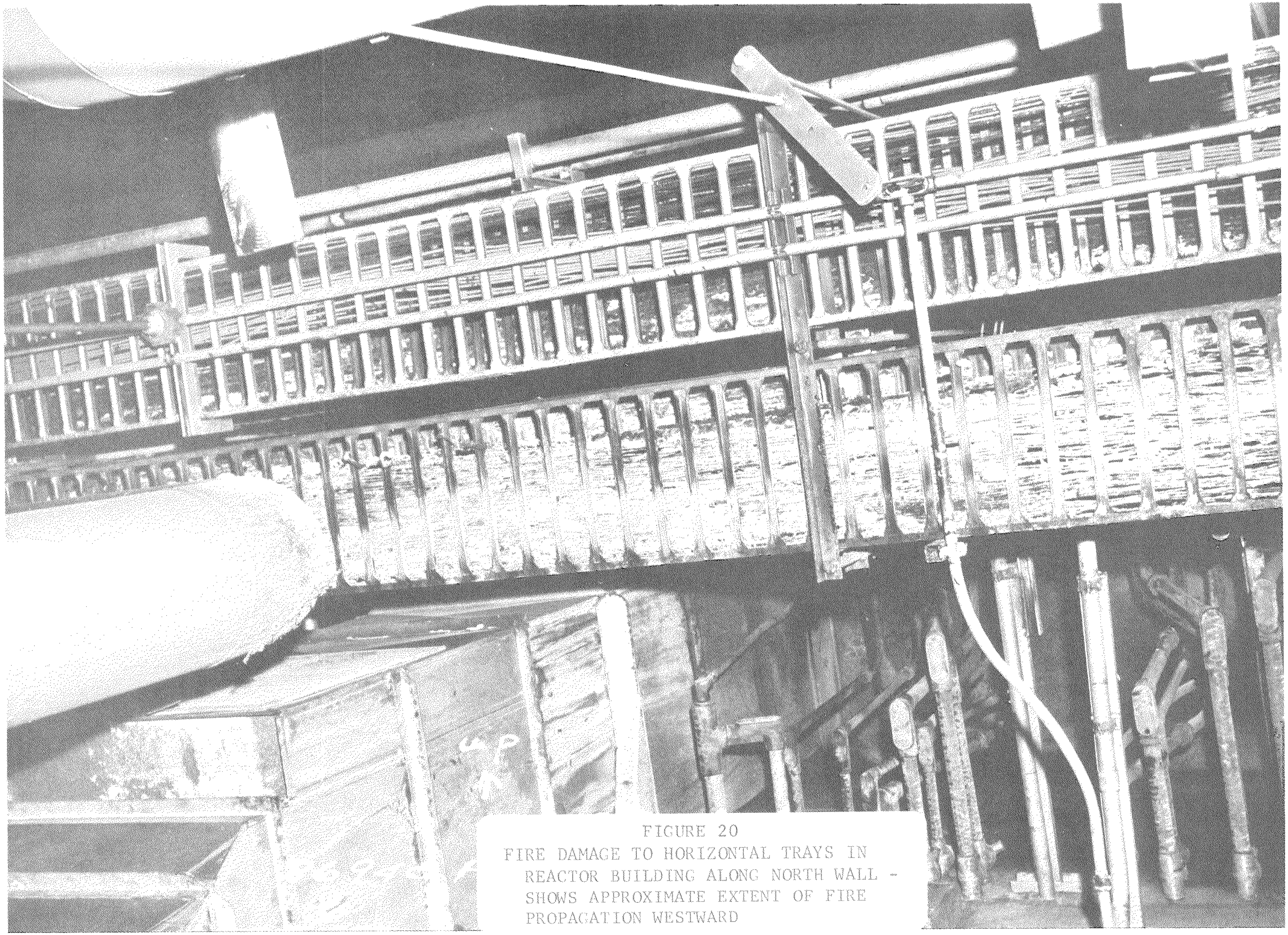


FIGURE 20
FIRE DAMAGE TO HORIZONTAL TRAYS IN REACTOR BUILDING ALONG NORTH WALL - SHOWS APPROXIMATE EXTENT OF FIRE PROPAGATION WESTWARD

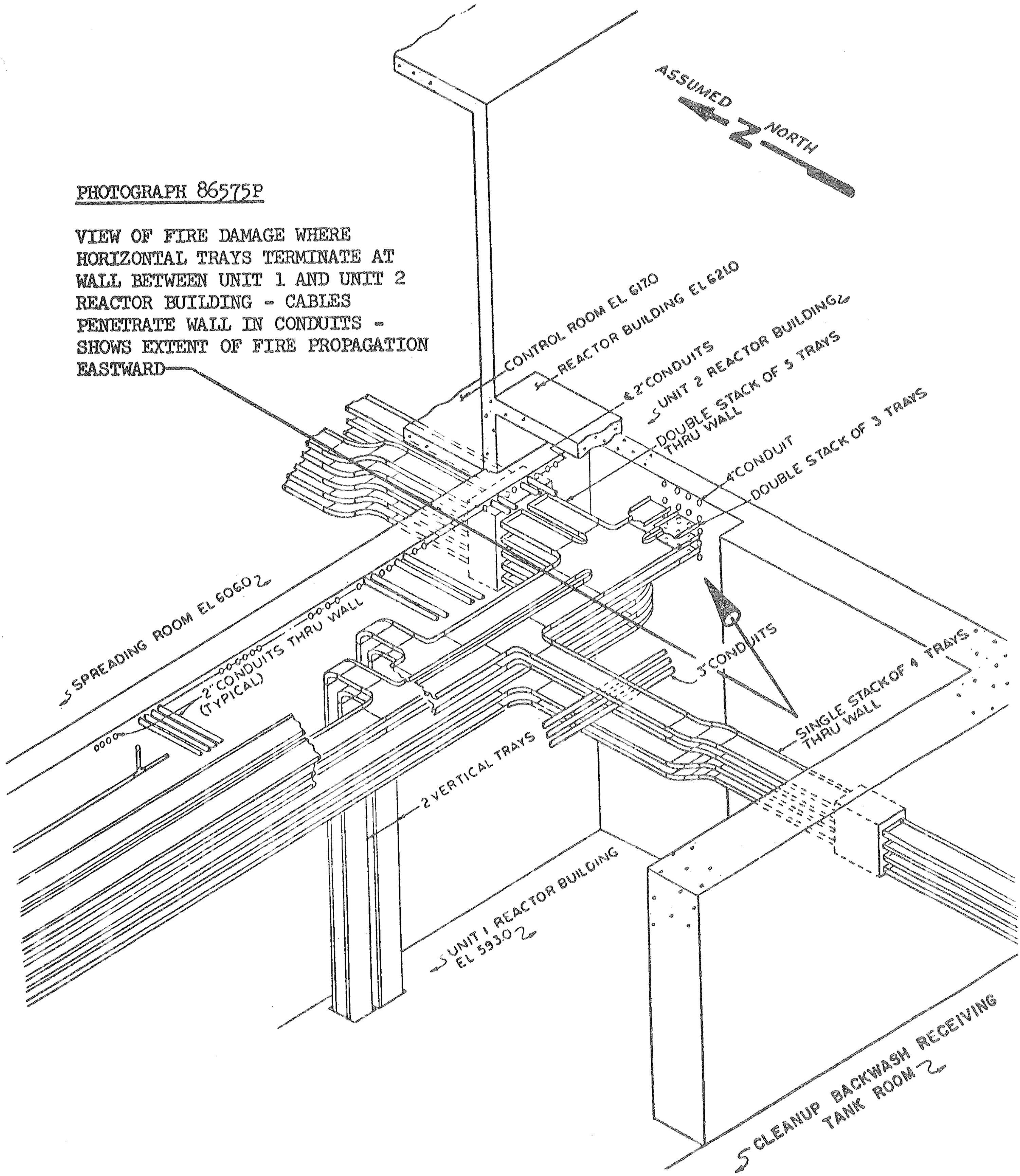


FIGURE 21
LOCATION WHERE PHOTOGRAPH 86575P WAS TAKEN

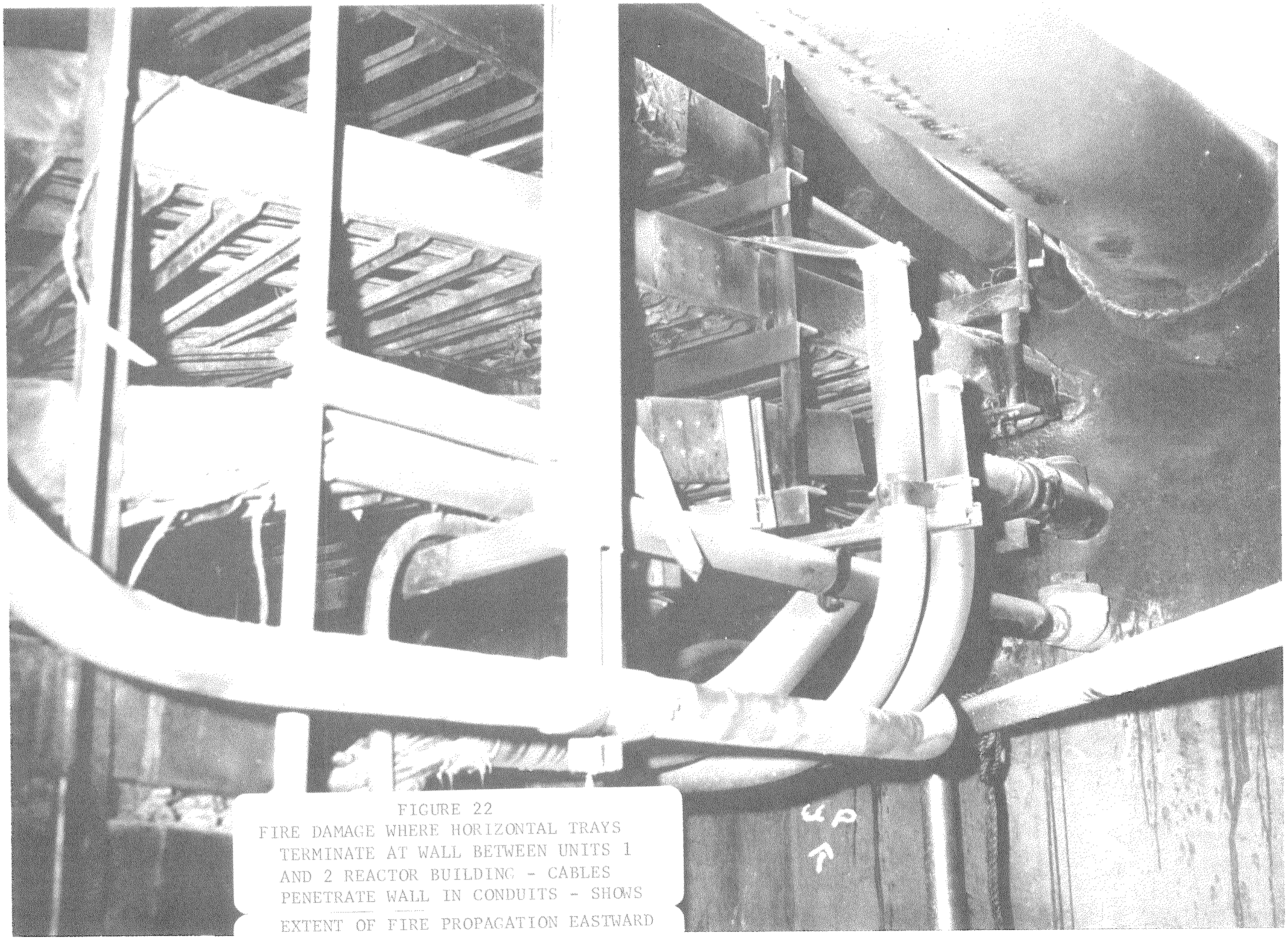


FIGURE 22
FIRE DAMAGE WHERE HORIZONTAL TRAYS TERMINATE AT WALL BETWEEN UNITS 1 AND 2 REACTOR BUILDING - CABLES PENETRATE WALL IN CONDUITS - SHOWS EXTENT OF FIRE PROPAGATION EASTWARD

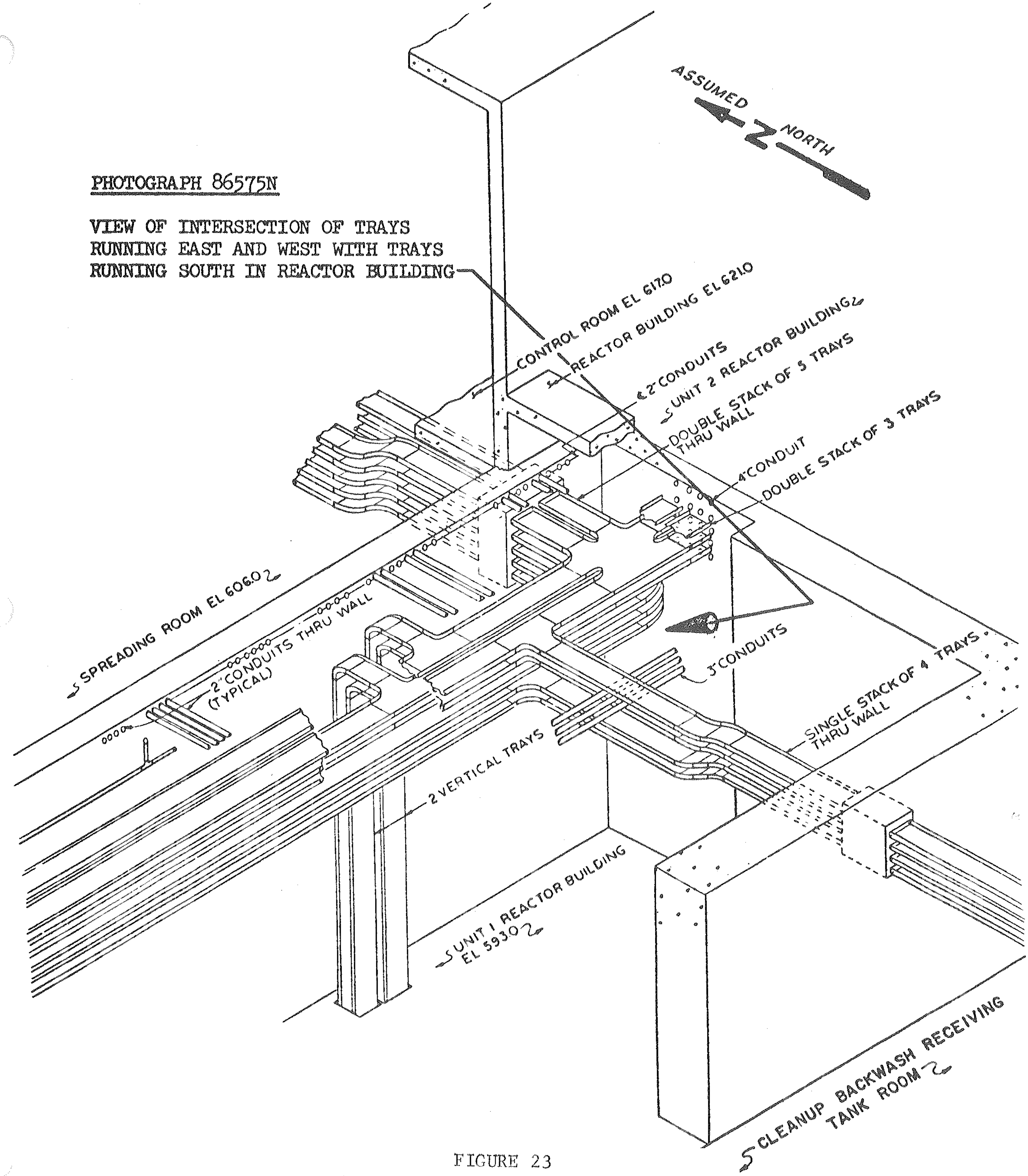


FIGURE 23
LOCATION WHERE PHOTOGRAPH 86575N WAS TAKEN

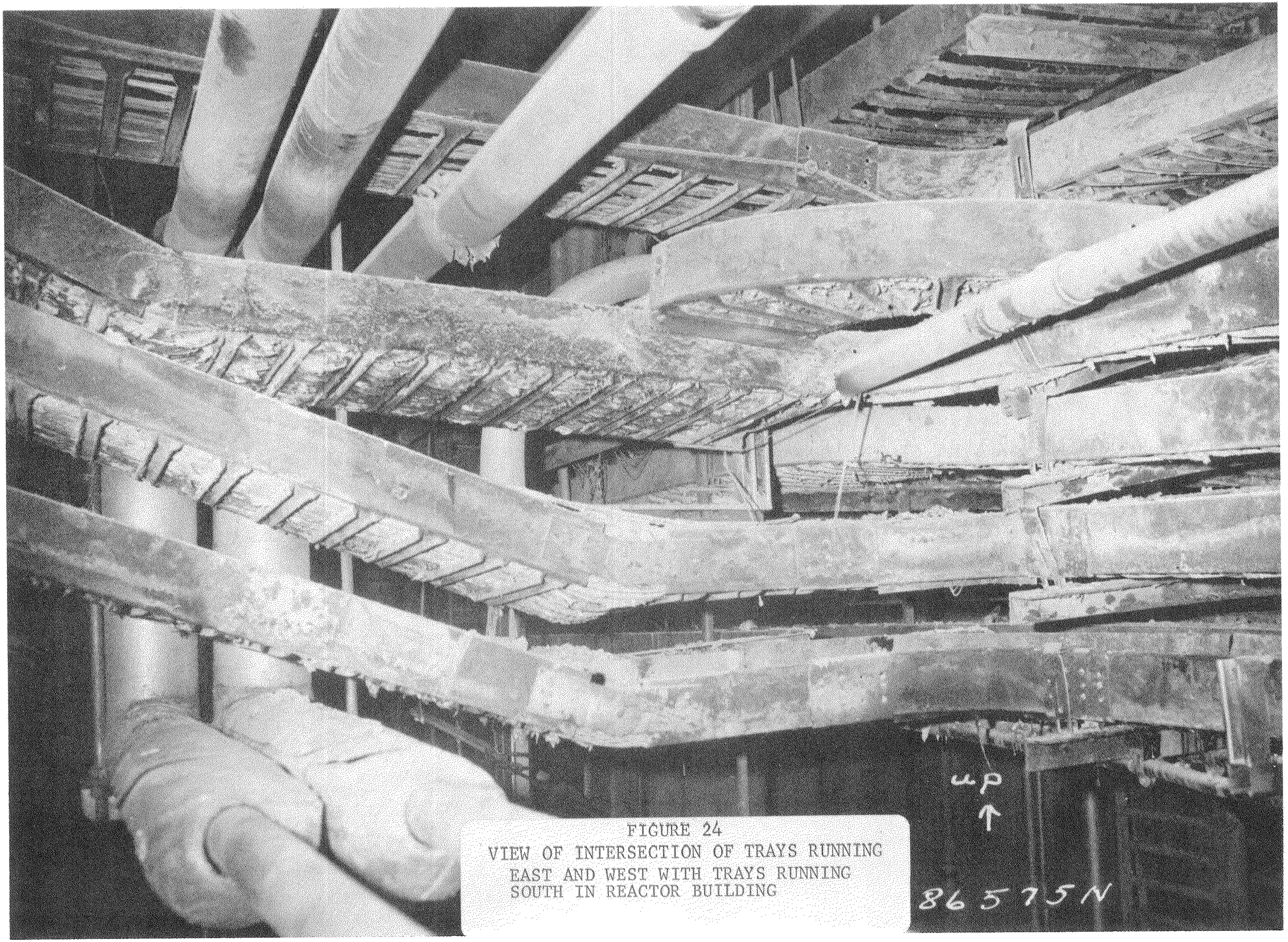


FIGURE 24
VIEW OF INTERSECTION OF TRAYS RUNNING
EAST AND WEST WITH TRAYS RUNNING
SOUTH IN REACTOR BUILDING

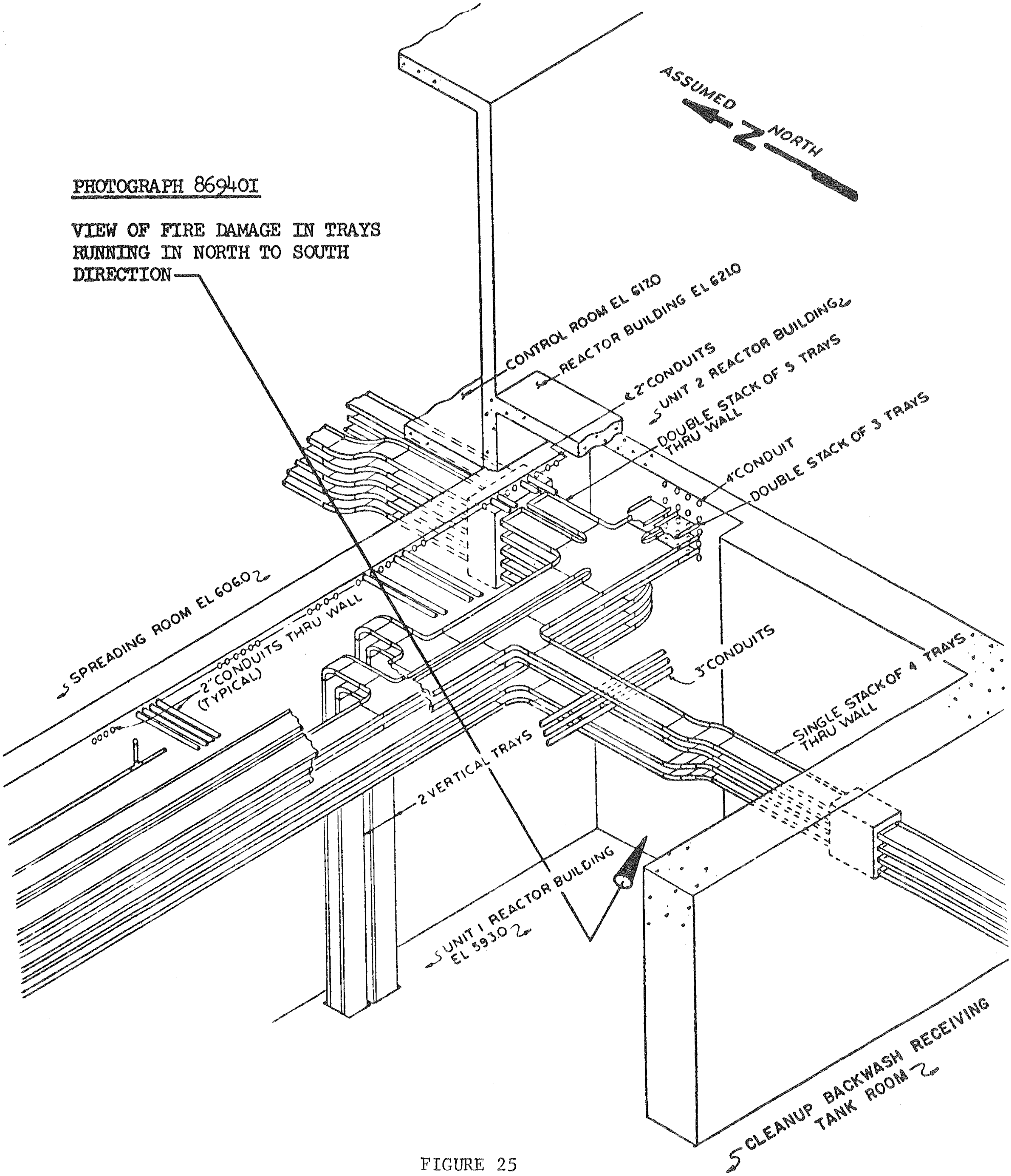


FIGURE 25
LOCATION WHERE PHOTOGRAPH 86940I WAS TAKEN

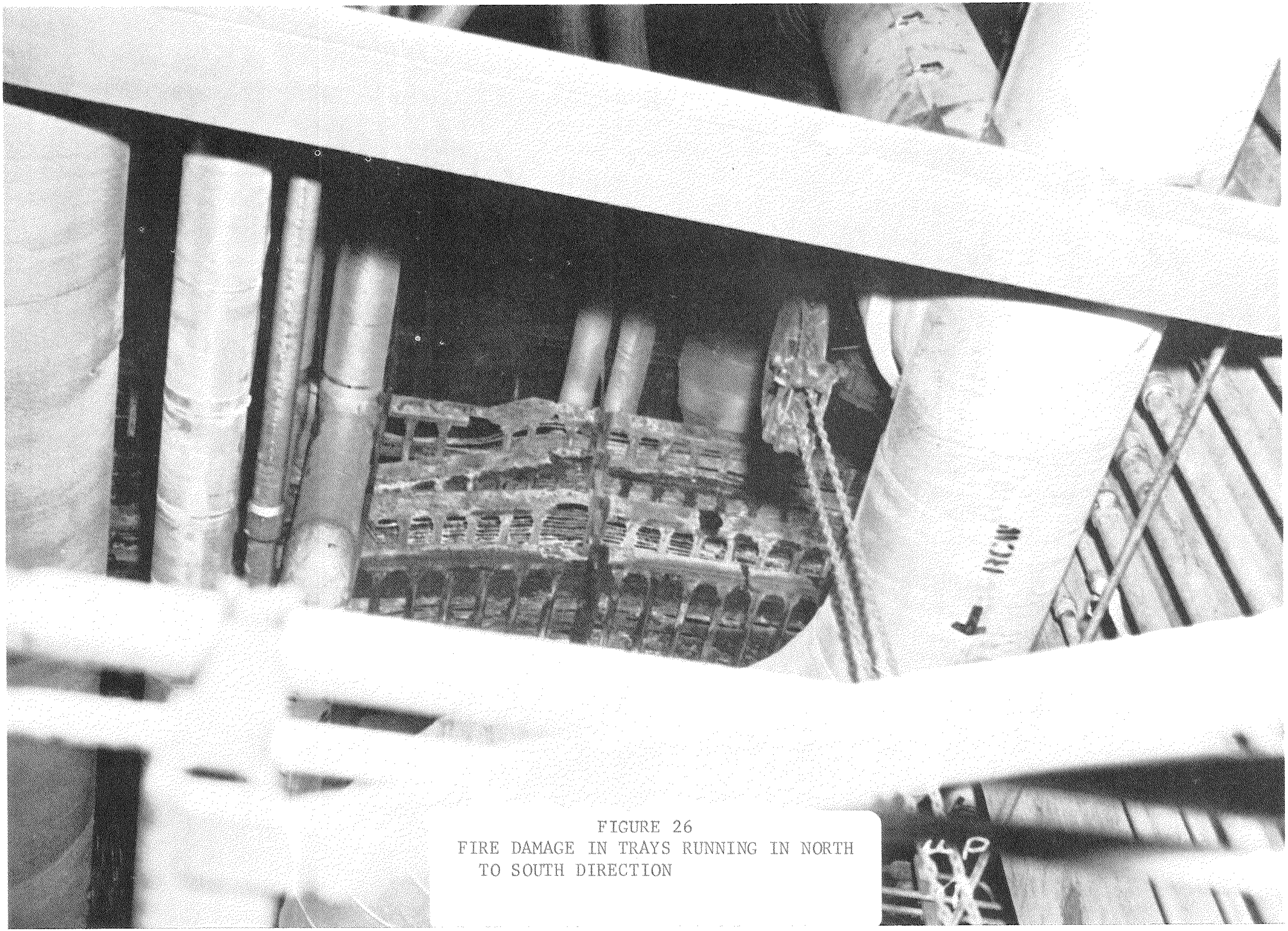


FIGURE 26
FIRE DAMAGE IN TRAYS RUNNING IN NORTH
TO SOUTH DIRECTION

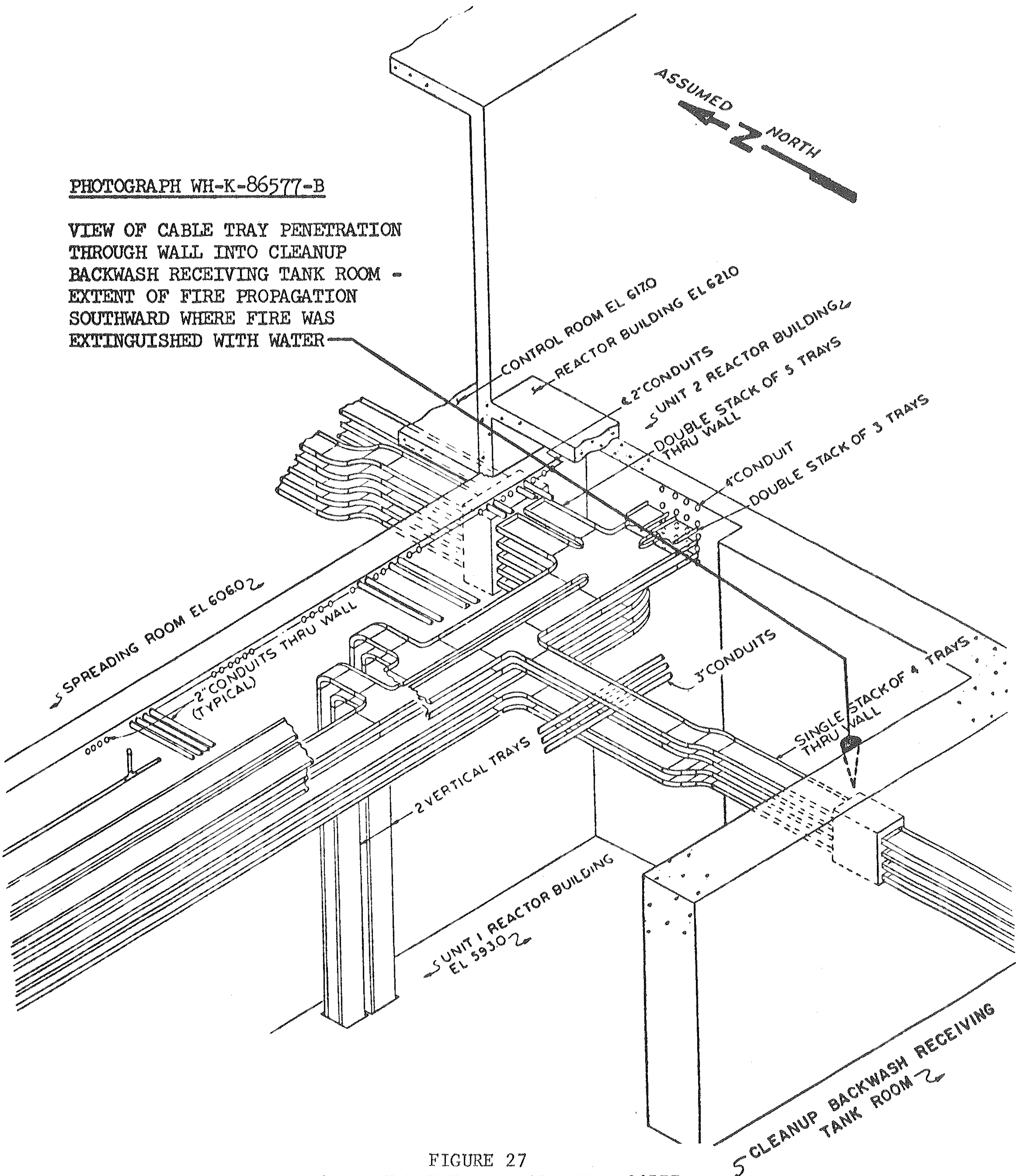


FIGURE 27
LOCATION WHERE PHOTOGRAPH WH-K-86577-B WAS TAKEN

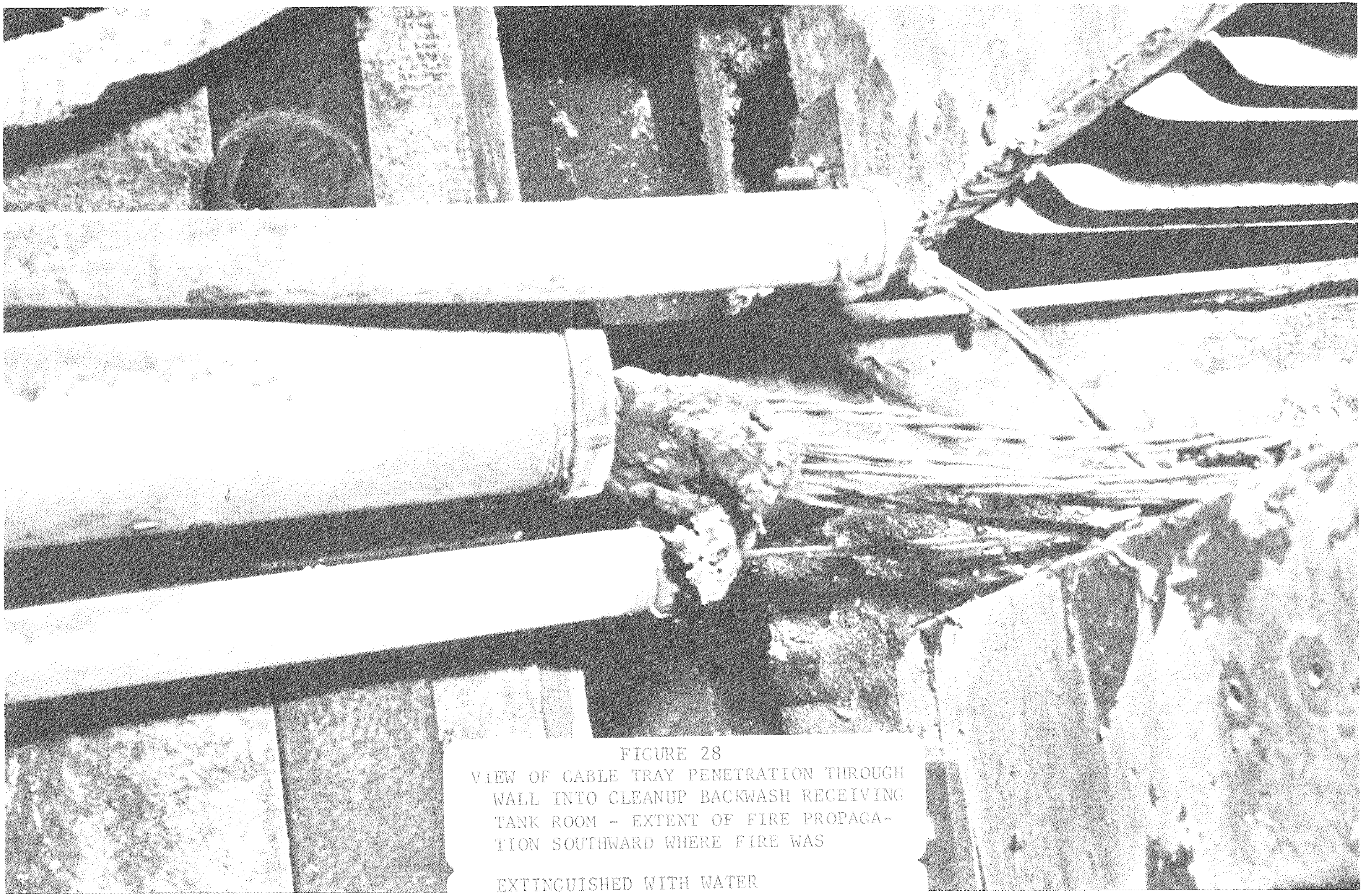


FIGURE 28
VIEW OF CABLE TRAY PENETRATION THROUGH WALL INTO CLEANUP BACKWASH RECEIVING TANK ROOM - EXTENT OF FIRE PROPAGATION SOUTHWARD WHERE FIRE WAS

EXTINGUISHED WITH WATER

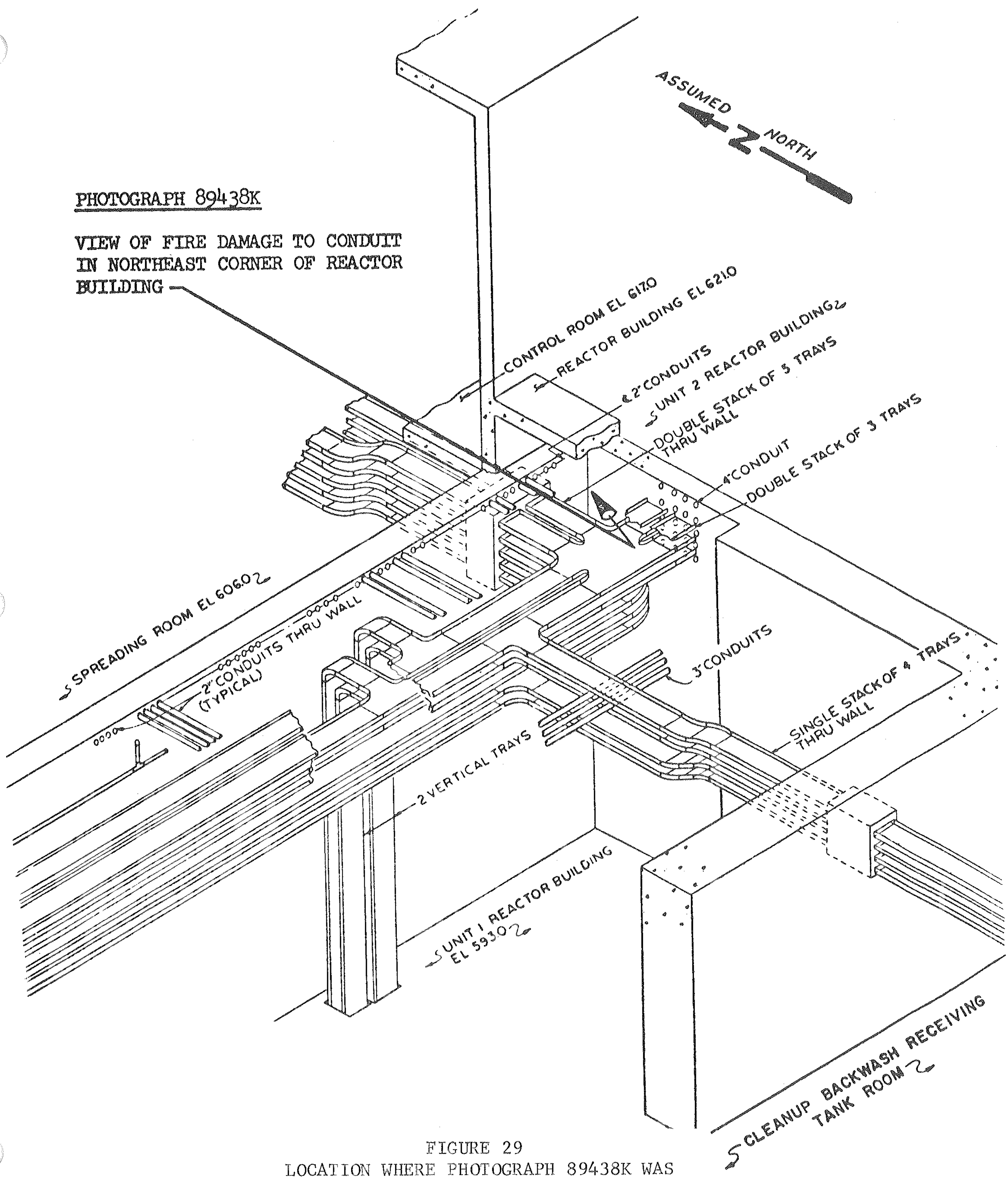


FIGURE 29
LOCATION WHERE PHOTOGRAPH 89438K WAS TAKEN

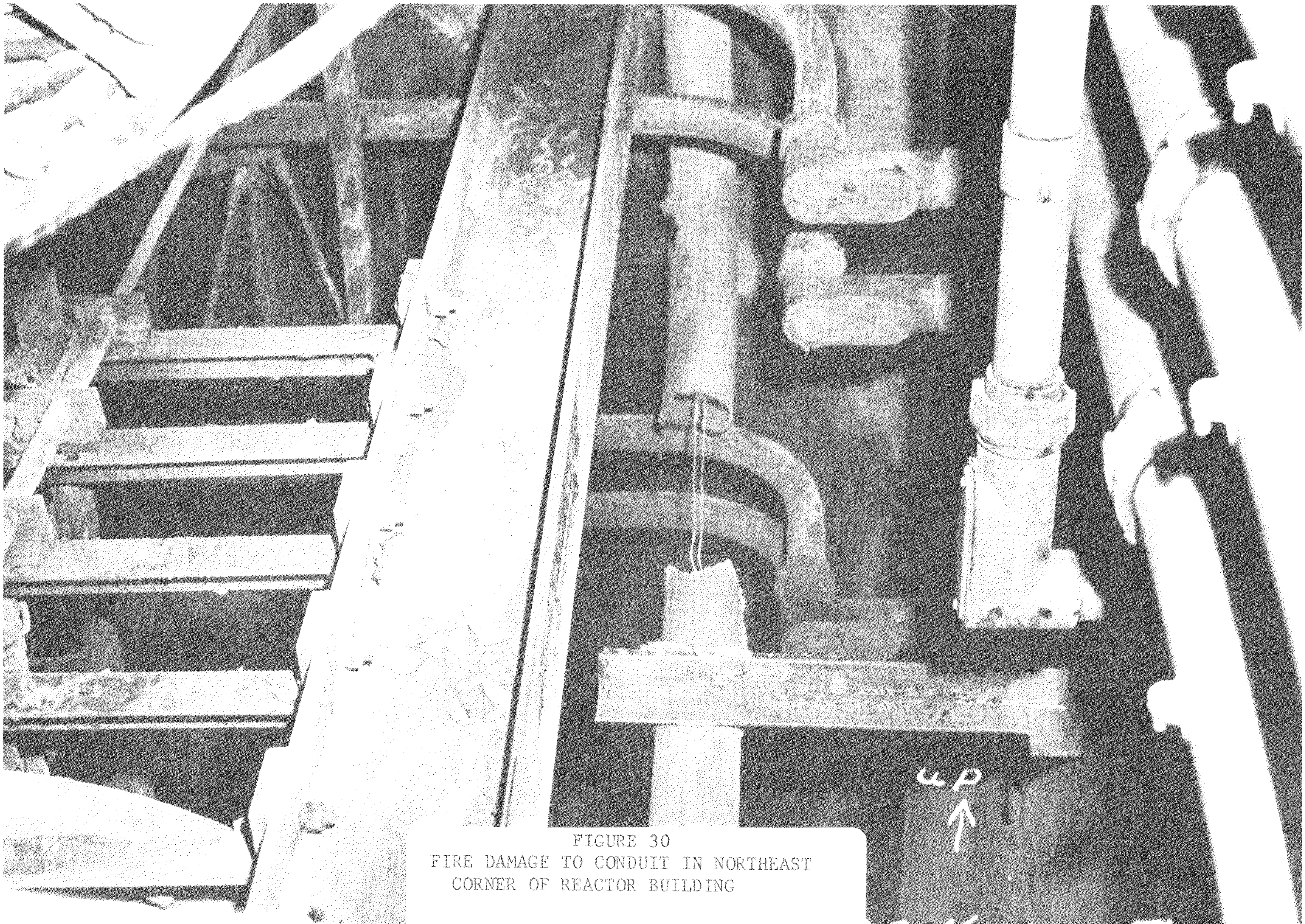
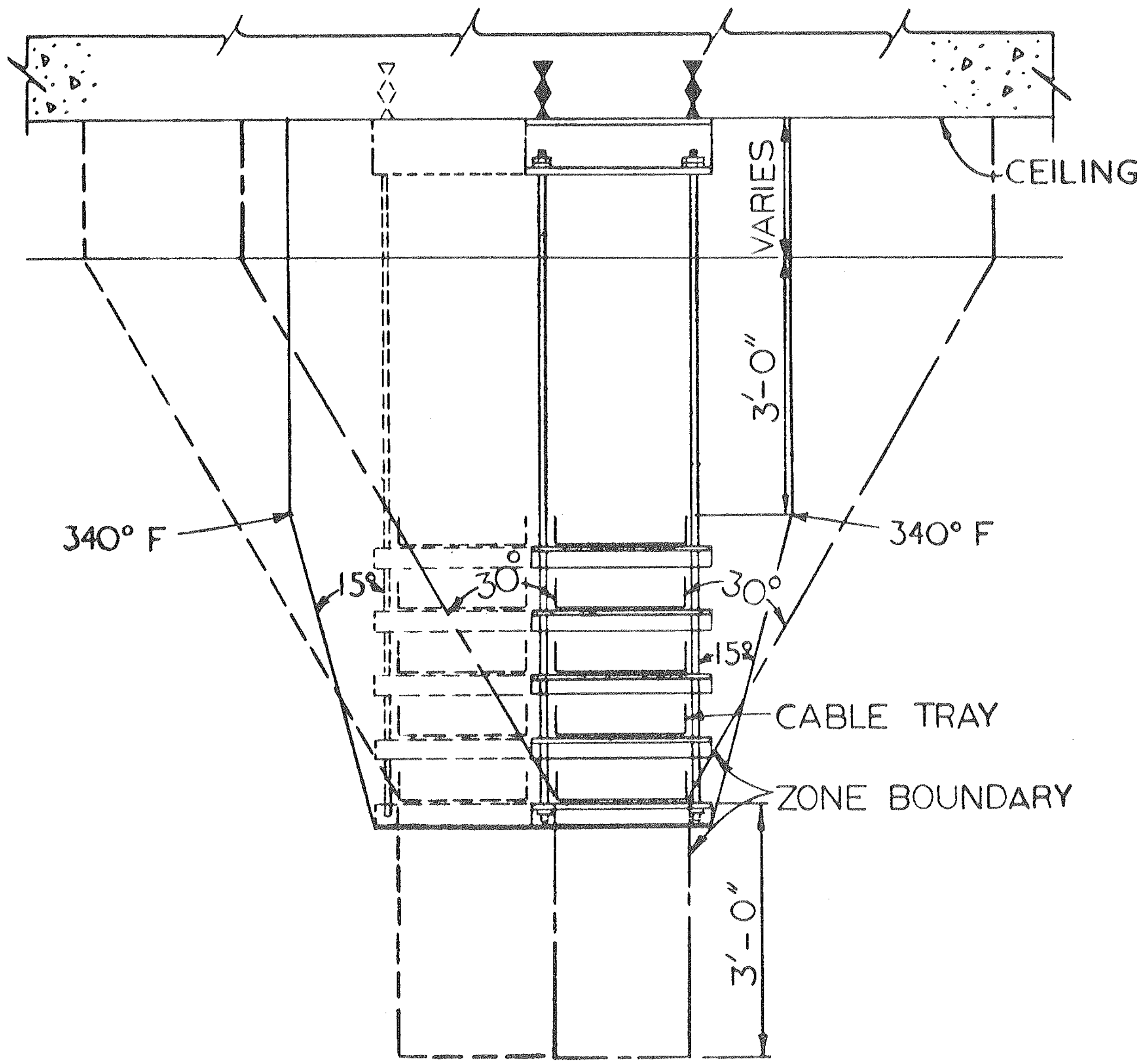


FIGURE 30
FIRE DAMAGE TO CONDUIT IN NORTHEAST
CORNER OF REACTOR BUILDING



REGION 31
REGION OF INFLUENCE OF FIRE IN CABLE
TRAY

SOCIETY OF FIRE PROTECTION ENGINEERS
60 Batterymarch Street
Boston, Mass. 02110
617-482-0686

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- Sharing in activities of committees at national level
- Public Information program

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